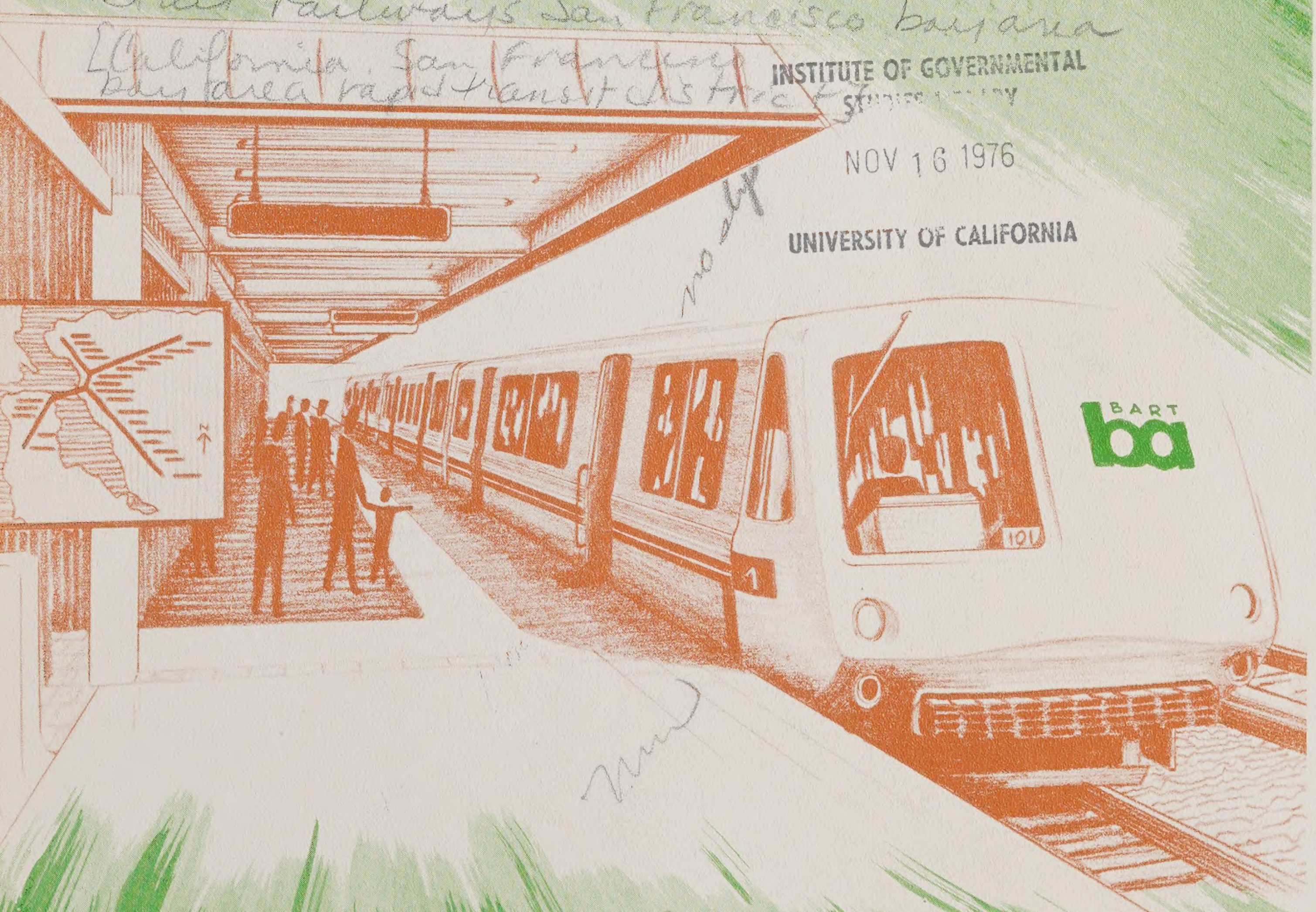
bart impact program

ENVIRONMENTAL IMPACTS OF BART: INTERIM SERVICE FINDINGS

Street railways San Francisco bay area
California. San Francisco bay area rapid transit district



final report

The BART Impact Program is a comprehensive, policy-oriented study and evaluation of the impacts of the San Francisco Bay Area's new rapid transit system (BART).

The program is being conducted by the Metropolitan Transportation Commission, a nine-county regional agency established by state law in 1970.

The program is financed by the U.S. Department of Transportation, the U.S. Department of Housing and Urban Development, and the California Department of Transportation. Management of the Federally funded portion of the program is vested in the U.S. Department of Transportation.

The BART Impact Program covers the entire range of potential rapid transit impacts, including impacts on traffic flow, travel behavior, land use and urban development, the environment, the regional economy, social institutions and life styles, and public policy. The incidence of these impacts on population groups, local areas, and economic sectors will be measured and analyzed. The benefits of BART, and their distribution, will be weighed against the negative impacts and costs of the system in an objective evaluation of the contribution that the rapid transit investment makes toward meeting the needs and objectives of this metropolitan area and all of its people.

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15. Supplementary Notes

16. Abstracts

This report is a summary of the results and accomplishments of the Environment Project's initial study phase. During this phase, the Project has concentrated on BART's immediate effects on the physical dimensions of the urban ecosystem. It has examined *what* aspects of the environment have been affected by BART, what physical and operational characteristics of BART *cause* the impacts, *where* the impacts are occurring, what are the demographic characteristics of those *who* are affected, and *how* can lessons from BART be used to guide decision-making on urban transportation and development in the Bay Area and elsewhere.

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BART IMPACT PROGRAM

ENVIRONMENTAL IMPACTS OF BART INTERIM SERVICE FINDINGS

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PHASE I REPORT

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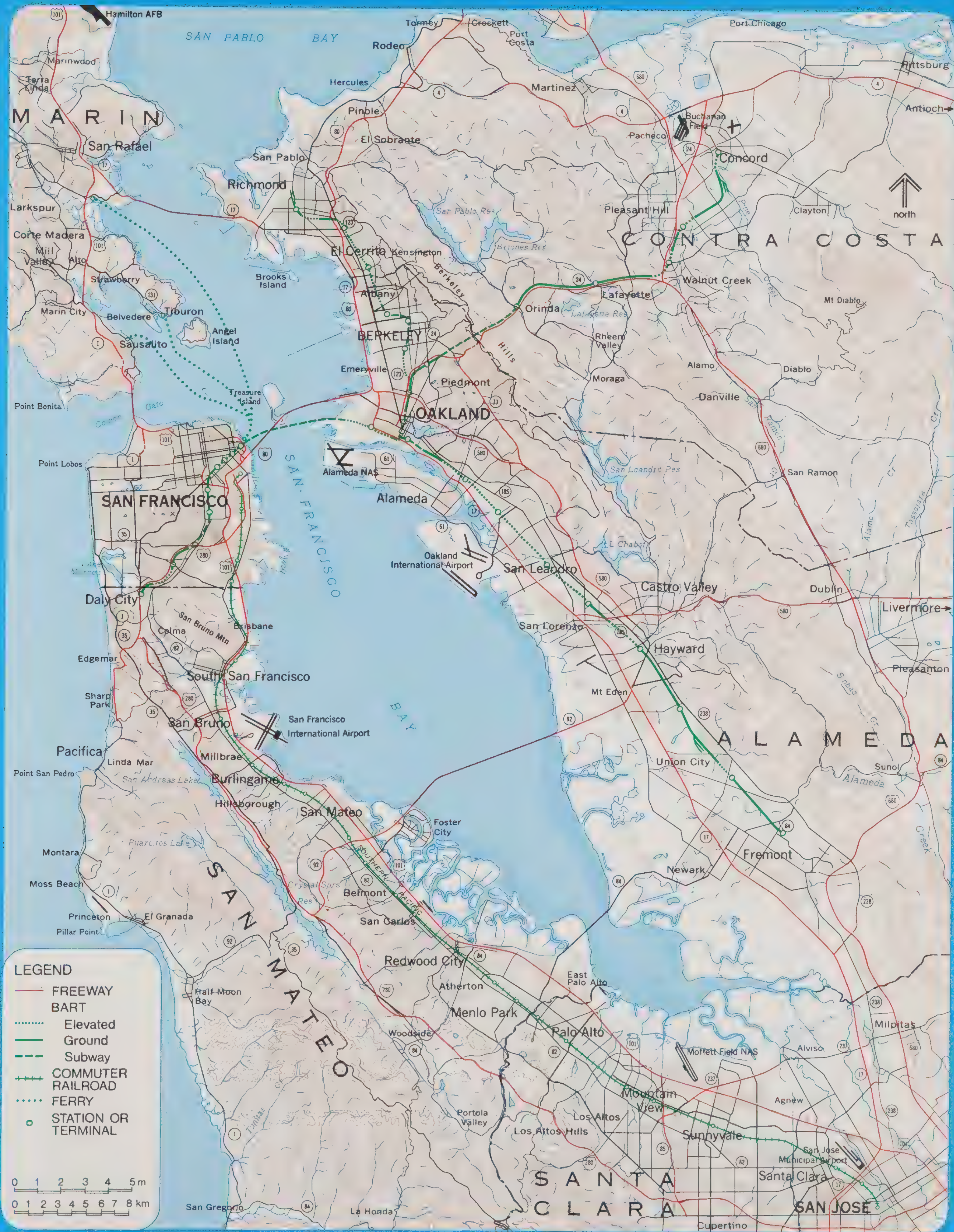

SAN FRANCISCO BAY REGION

CENTRAL AREA

SUMMARY: MAJOR PHASE I FINDINGS

The Environment Project is one of six major studies which form the BART Impact Program,[1] and focuses on the effects of BART's physical presence on its surroundings. The "environment" is defined broadly to include five environmental components, with several impact categories within each:

Table 1
ENVIRONMENTAL COMPONENTS AND IMPACT CATEGORIES

Environmental Component	Acoustic	Atmospheric	Natural	Social	Visual
Impact Categories	- Sound - Vibration	- Regional air quality - Local air quality - Microclimate	- Biota - Soils and geology - Drainage and water	- Barriers - Safety - Security - Visual exposure	- Visual quality - Illumination - Shadows

This report's presentation of BART's impacts on the environment is incomplete for two reasons. First, BART was in an interim stage of operations during the study. As of the end of Phase I in 1975, it operated only on weekdays and only until 8:00 p.m. Trains did not run as frequently as planned for ultimate full service, and patronage was at about 60 percent of the level predicted for full service. Second, the report covers only Phase I of the project, in which the observable effects of BART were assessed. Phase II will extend this assessment and also include several additional studies:

- The perceptions and feelings of people affected by those impacts.
- "Indirect" environmental impacts (those caused by BART-induced land development).
- Corresponding impacts of a "No-BART Alternative" transportation system.
- Physical effects experienced by BART travelers.

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[1] The others: Land Use and Urban Development, Institutions and Life Styles, Transportation System and Travel Behavior, Economics and Finance, and Public Policy.

This summary of the major Phase I findings and conclusions is organized to address the following key issues:

- What are the environmental effects of BART?
- Why do these impacts occur and others not occur?
- Where do these impacts occur?
- Who are most affected?

A brief description of BART's major environmentally-relevant attributes provides a useful background for presentation of these findings. Figure 1 displays the BART system in its Bay Area settings. Table 2 describes key features of BART and its environment. More detailed descriptions are available in a subsequent chapter and other project reports.

Figure 1
BART AND THE BAY AREA

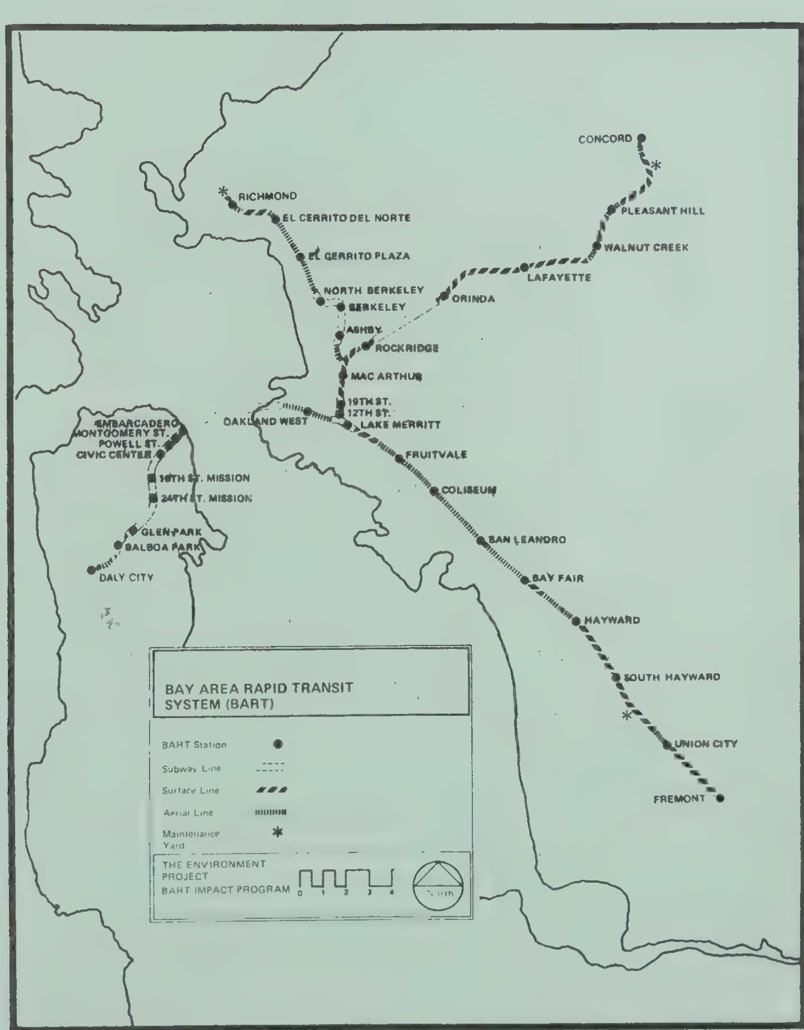
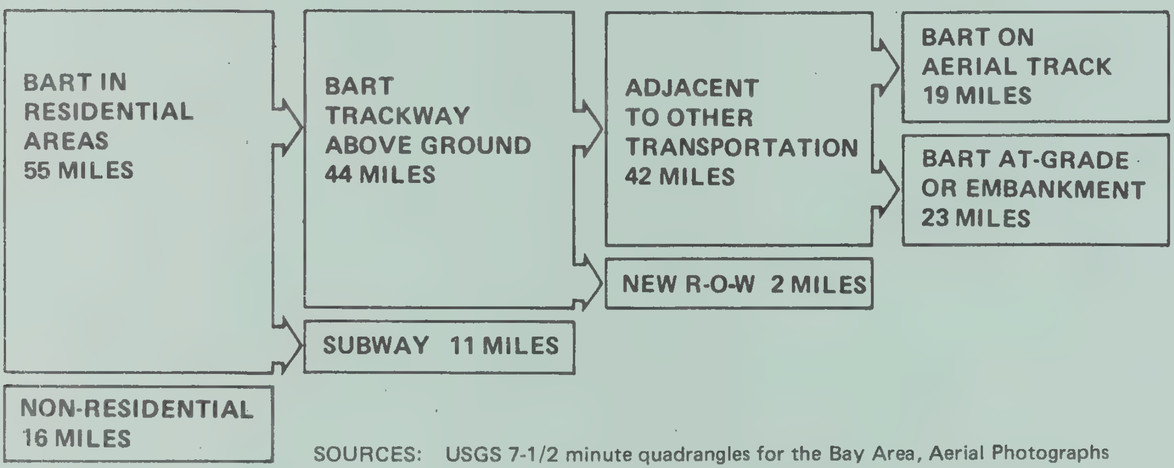


Table 2
BART AND ITS ENVIRONMENT

I. BART ATTRIBUTES: FACILITIES			
Configuration	Aerial structure	24 miles	13 stations
	At-grade/embankment	27 miles	7 stations
	Subway	13 miles	14 stations
	Transbay Tube and Orinda Tunnel	7 miles	–
	Totals	71 miles	34 stations
Parking Facilities	Stations with parking		23
	Total spaces available		approximately 18,000
	Individual lot capabilities		240 to 1,400 cars
	Lot sizes		2 to 8 acres
Trackway Details	Switches (crossovers and turnouts)		93
	Tunnel portals		15
	Bridges (over 200 feet)		31
	Linear park (under aerial track)		2.7 miles
II. BART ATTRIBUTES: OPERATIONS (JANUARY 1975)			
Patronage	One-way trips/day		approximately 120,000
	Range by station		2,000 to 42,000
Parking Lot Use	Overflow		at 10 of 23 lots
Hours of Service	Weekdays only		6:00 am to 8:00 pm
Train Characteristics	Length		140 to 700 feet (2 to 10 cars)
	Frequency		6 to 12 minutes
	Speed		80 mph maximum, 42 mph average
III. BART'S ADJACENT ENVIRONMENTAL CHARACTERISTICS			
Adjacent Land Use	Residential		55 miles
	Non-residential		16 miles
Adjacent Transportation Facilities	Freeway		14 miles
	Arterial		18 miles
	Railroad		27 miles
	(Tube and tunnel)		8 miles
	New rights-of-way		4 miles

Of particular significance for environmental impact is the relationship of BART's adjacent land use, configuration, and adjacent transportation facilities in combination. This is summarized in Table 3, showing that, although BART is above ground through most of the residential areas traversed, virtually all of this trackway mileage is also adjacent to other transportation facilities.

Table 3
BART CONFIGURATION AND USE OF OTHER TRANSPORTATION ROUTES IN RESIDENTIAL AREAS



SOURCES: USGS 7-1/2 minute quadrangles for the Bay Area, Aerial Photographs (1972 pre-BART Series), BART Track Charts ("as-built" drawings)

WHAT ARE THE ENVIRONMENTAL EFFECTS OF BART?

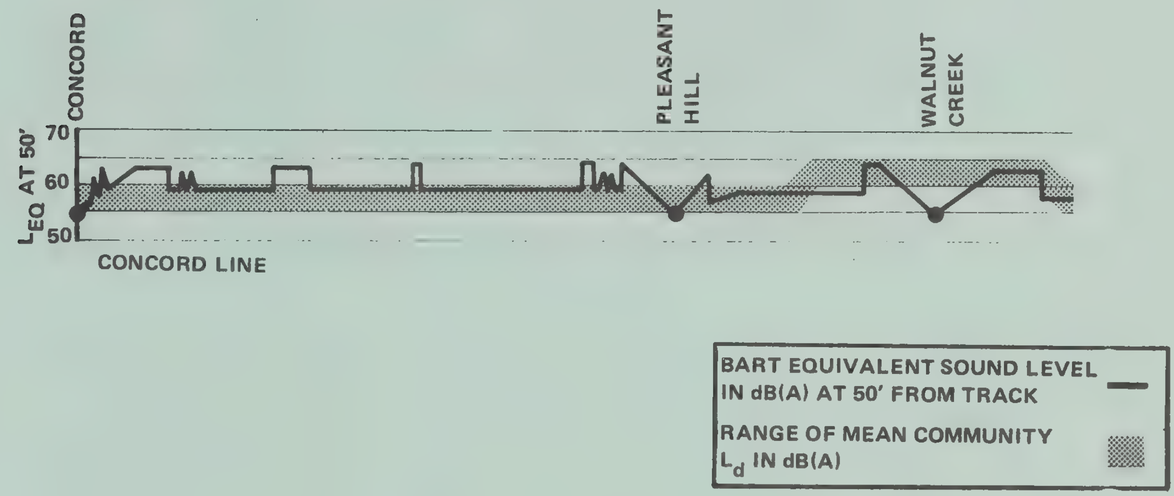
BART's present environmental impacts were found to be generally small and scattered throughout the system.

- Atmospheric Environment: BART's net effect on regional air quality has been a small reduction in pollution. BART-related traffic in and around its station parking lots has produced some local air pollution, but at very low levels. The effect of BART on local wind and temperature has been minimal.

- Acoustic Environment: BART-generated sound was found to exceed estimated ambient community sound levels, and thereby increased total ambient sound levels significantly, along approximately nine miles of its aerial lines. These affected areas are very near (usually within one block) the tracks and are predominantly residential. BART sound levels alongside surface lines

did not increase total ambient sound significantly. Figure 2 shows this comparison of BART and community sound levels for a typical line segment. BART train vibration levels on aerial and subway track were found to be similar to those of passing delivery trucks.

Figure 2
TYPICAL BART AND COMMUNITY SOUND LEVELS



- Natural Environment: BART's construction and operation have not resulted in significant impacts on biota, soils, and drainage systems.

- Social Environment: BART has created few physical barriers to pedestrian and vehicular movement and in some cases has improved such movement. BART's only impacts on safety are related to local and BART-bound traffic; at some heavily used suburban stations, increases in congestion and accident rates were observed. Crime associated with BART has been minimal, consisting primarily of auto theft and related property crimes in its parking lots. There has been considerable visual exposure (to BART riders) of previously private areas such as backyards, but no indication of significant concern by those affected.

Plate 1
DALY CITY BART STATION

- <u>Visual Environment</u>: BART's impact on <u>local visual quality</u> has varied, enhancing some downtown areas, shopping centers, and industrial areas, while creating visual contrast or conflict in scale with the appearance of residential areas near its aerial lines and stations. It has reinforced existing centers of population and activity visually and functionally by locating its major stations in the downtown areas of San Francisco, Oakland, and Berkeley and by inducing municipal improvement projects that were coordinated with BART's construction.

Plate 2
HALLIDIE PLAZA—DOWNTOWN SAN FRANCISCO

In the future, some adverse impacts on the environment are likely to increase substantially.

- Evening and weekend service and more frequent trains will extend BART's acoustic impacts to cover the blocks abutting most of its above-ground trackway.

- Further increases in BART patronage are likely to generate safety problems at most suburban stations, due primarily to expected congestion of buses, autos, and pedestrians near station entrances.

- Expected increases in BART patronage will not result in substantial further improvements in regional air quality. At the same time, local air pollution at station parking lots will not become significant problems, because present effects even at busy stations are very small.

- There is no evidence that any other impacts will increase, since most are not related to aspects of BART which are expected to change (i.e., patronage and level of service).

WHY DO THESE IMPACTS OCCUR AND OTHERS NOT OCCUR?

BART's impacts vary significantly, depending on its adjacent environment as well as its physical facilities and operations.

- Atmospheric impacts have been caused primarily by BART-induced changes in automobile use. Traffic to, from, and within BART's parking lots in the peak commute hours has caused the observed small increase in local air pollution at the stations. A shift from auto to BART use has improved the region's air quality, although its net effect is very small. Changes in local wind patterns and velocity occur when the wind is channeled under structures (aerial stations and trackway) or across open parking lot areas.

- Acoustic impacts have been primarily due to the sound created by the wheel-on-rail contact of BART trains operating in quiet residential neighborhoods. Significant increases in sound impact were found to be caused by increasing the train's speed, service frequency, and length; use of aerial concrete trackway

structures in contrast to an at-grade (or embanked) configuration; and the presence of certain trackway features including bridges, switches, curves, and tunnel portals. BART-related vibrations occur above subway portions of the system and next to aerial line segments.

Plate 3
AERIAL GUIDEWAY IN A RESIDENTIAL AREA—ALBANY

- The few natural environmental impacts which were found (generally minor erosion and land slippage) were caused primarily by the deepening of existing hillside slope excavations for trackway placement in the unstable soil material of the Berkeley Hills near Orinda.

- The social environmental impacts studied had a variety of causes. Barriers were potentially created primarily by the 27 miles of at-grade trackways. However, virtually all such trackage is adjacent to prior transportation facilities (freeways, arterials, railroads) across which movement was already limited. Safety from accidents has been impaired mainly by the increase in auto traffic around BART stations with parking lots, as well as by parking lot designs which have led to mixing of pedestrians, autos and buses at some station entrances and driver confusion due to nonstandard parking lot traffic signing. Security of persons and property was affected only by auto theft in the unattended BART parking lots. Visual exposure occurred where BART on aerial lines in residential areas permitted BART riders to look into houses, apartments, and their backyards.

Plate 4
BART STATION
PARKING LOT—
EL CERRITO DEL
NORTE

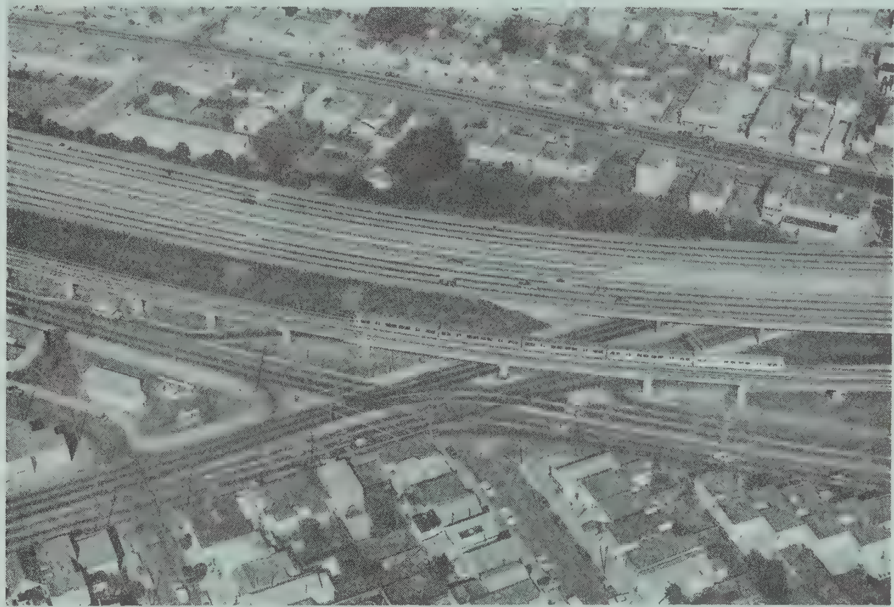
- Visual impacts found to be adverse have been caused primarily by the contrast of BART's large above-ground station structures, parking lots, and aerial trackway with their often small-scale residential surroundings. These impacts have been intensified by the generally low-to-moderate level of BART landscaping. Beneficial visual impacts have been due largely to the open green spaces of the linear parks along portions of the aerial trackway, as well as to the pedestrian emphasis of the extensive BART-related street improvements (wide brick sidewalks, lights, benches, etc.) above the four subway segments in downtown areas.

Plate 5
MARKET STREET
REFURBISHING

BART's environmental impacts have not been more extensive due both to a generally high level of already-existing impact and the use of some low-impact BART design features in many other locations.

- For 42 of BART's 44 above-ground miles in residential areas, the lines are adjacent to other transportation facilities, such as freeways, arterials and railroads. Most, although not all, of these were already producing so much impact that BART's additional impact has not been very noticeable.

Plate 6
BART AND ADJACENT TRANSPORTATION FACILITIES



- Approximately nine miles of BART lines are in areas of relatively undeveloped or open land, so that disruption of human activity has been minimal.

- The few natural environments traversed by BART are generally water and grasslands which are not sensitive to its impacts.

- Nearly one-third of BART's lines and stations are underground, causing virtually no adverse impact beyond that which occurred during construction.

- Due to BART's heavy use of existing transportation rights-of-way, land taking has been held to a minimum except at stations with parking lots.

- BART's projected full level of service and patronage has not yet been achieved, resulting in only partial effects on sound, safety, security and, to a lesser extent, air quality.

- Apart from some problems of contrast with residential surroundings, BART's architectural design appears to have been generally and consistently of high quality.

WHERE DO THESE IMPACTS OCCUR?

The most significant adverse environmental impacts have occurred primarily at stations with parking lots throughout the system, as well as along parts of the aerial trackway.

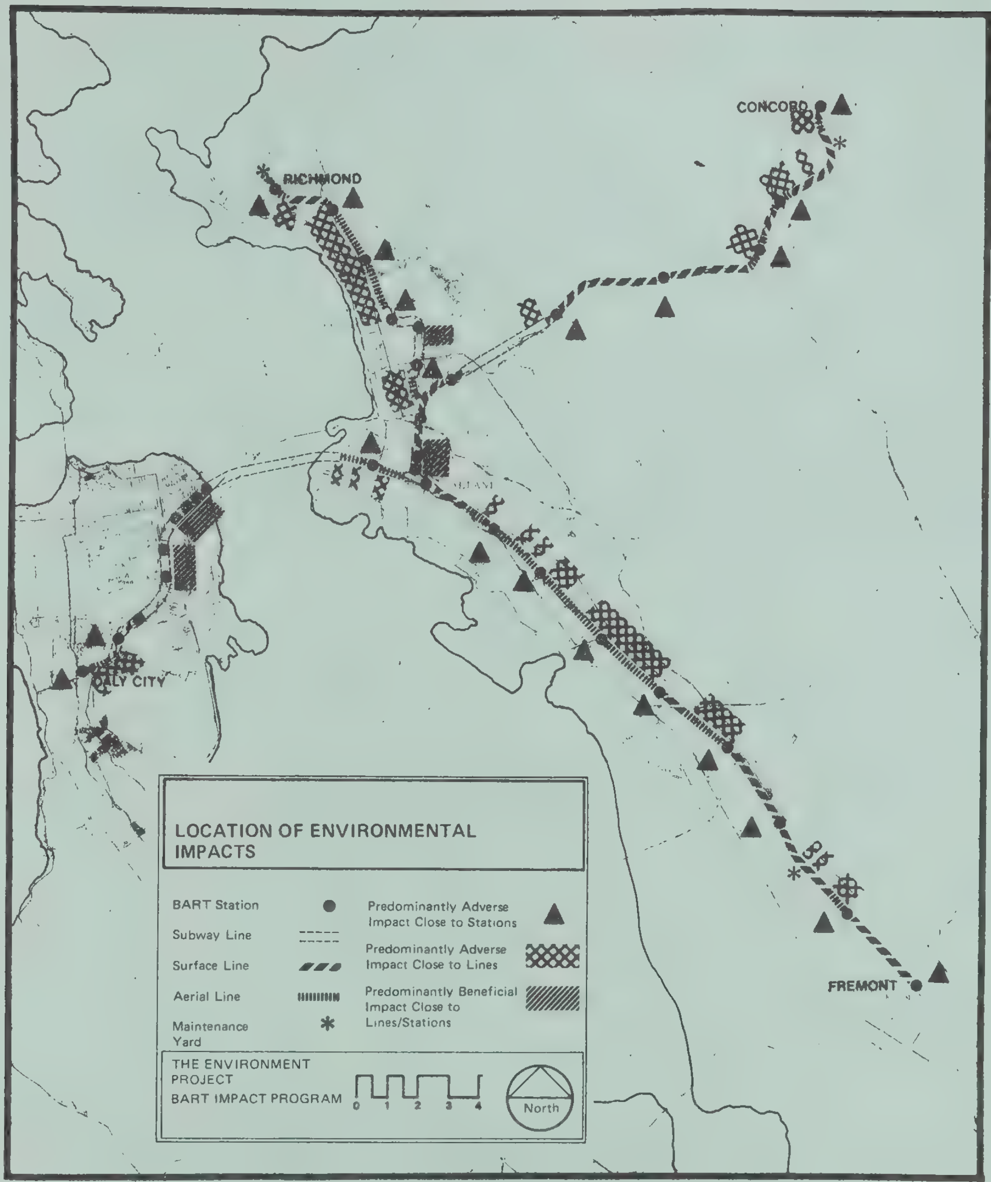
- At BART's 23 non-downtown stations with parking lots, a number of key determinants of adverse impact tend to occur together. These include the large size of the station structures, the large land area used, traffic movement in and around the lots, general use of aerial trackway at the station, generally low level of landscaping, bright lighting of parking lots, and location in or abutting residential areas.

- Along much of the 19 miles of aerial trackway in residential areas, adverse impacts have included the visually prominent structure, increased sound, vibration, and shadow. The at-grade (or embanked) configuration in residential areas caused strong barrier effects.

- Many other adverse impact causes have tended to occur together in specific locations along the aerial lines. These include high train speed and frequency, trackway curves and switches, the use of a very narrow right-of-way, and location in residential areas.

- No significant adverse impacts of subway lines were identified, beyond the initial disruptive effects of construction.

Figure 3
LOCATION OF ENVIRONMENTAL IMPACTS



<u>The most prominent beneficial impacts have occurred primarily at major downtown subway stations.</u>

- In four downtown areas (Market Street and the Mission district in San Francisco, Oakland, and Berkeley), the extensive street refurbishing stimulated by the BART subway construction has been a major environmental improvement. Since these streets were largely removed for BART construction, local businesses and cities took the opportunity to replace them with much improved facilities.

- In several locations such as between the Pleasant Hill and Concord stations, the use of trackway embankments assisted in visually separating residential and industrial land uses.

Under projected full BART service, additional adverse impacts will occur at most stations with parking lots and most of the above-ground lines.

- Future increases in adverse environmental impacts at stations will be at those with parking lots because of increased station-oriented traffic.

- Adverse impact increase along lines will be especially extensive throughout the Fremont line and portions of the Concord line, because of their low-density residential character.

- No significant increase in beneficial environmental impacts is to be expected beyond those estimated for the present.

WHO ARE MOST AFFECTED?

Few people live in the areas affected by BART's impacts.

- Since BART's major impacts lie primarily within a few hundred feet of the track, the residential areas affected are narrow. Approximately three percent of the population of the three-county BART area live in the census blocks abutting BART, but, of this group, only a small proportion are near its present locations of environmental impacts.

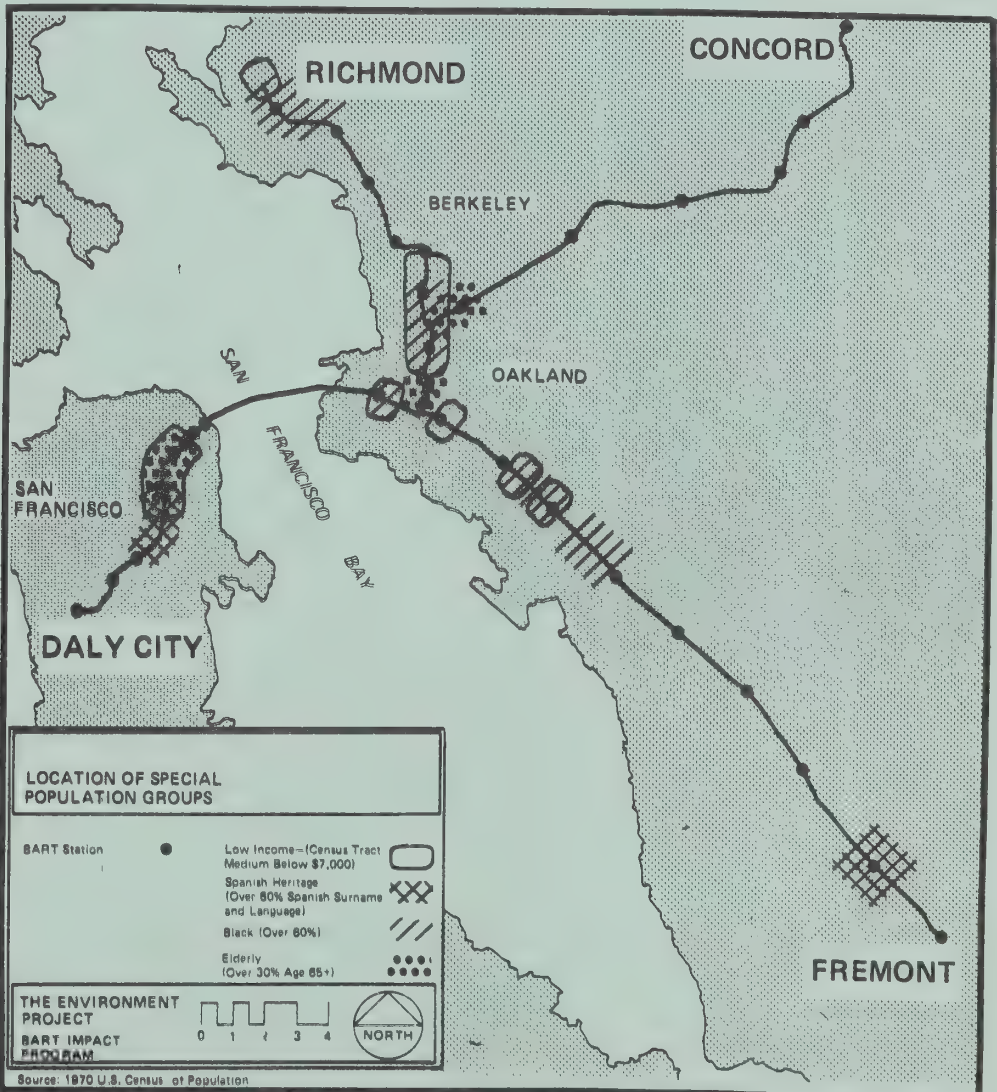
Table 4
1970 BAY AREA POPULATION BY DISTANCE FROM BART

Area	Population	Percent
Nine-county Bay Area	3,109,519	—
Three-county BART area	2,347,247	100.0
Census tracts abutting BART	744,914	32.0
Census blocks abutting BART	68,648	3.0
- Aerial BART configuration	21,109	0.9
- Stations with parking lots	8,137	0.3

Most of BART's adverse environmental impacts have been borne by middle- and upper-middle-income groups living near suburban stations and above-ground lines.

- Concentrations of low-income families, blacks, persons of Spanish heritage[1] and elderly occupy a small proportion (less than 25 percent) of the locations of BART's adverse environmental impacts in residential areas.

Figure 4
LOCATION OF SPECIAL POPULATION GROUPS



- BART's environmental impacts judged as beneficial occur primarily in CBDs and other commercial areas, virtually not at all in residential areas.

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1 Reflecting the geographic heterogeneity of persons of Spanish-speaking background, the Bureau of the Census uses a variety of descriptions to refer to this group, depending on their locations in the U. S. and on the data source. Socioeconomic data pertaining to "persons of Spanish heritage" are derived from the census' 1970 15-percent sample. For California, this group is defined as "persons of Spanish language or Spanish surname."

I. INTRODUCTION

PURPOSE OF THIS REPORT

The Phase I Report is an interim presentation of significant findings regarding the environmental impacts of BART--the Bay Area Rapid Transit System. Although the project is now at its midpoint, many of these interim results are of immediate use in decision-making relative to transit planning here in the Bay Area and elsewhere across the nation where rapid transit systems are under consideration.

In addition to this report, the full documentation of the findings of Phase I is organized into a series of reports, consisting of planning documents, technical memoranda, and working papers. A complete list of references is provided at the end of this report. Specific findings cited in this report are cross indexed to the technical memoranda (TM) and working papers (WP) which contain more detailed supporting documentation.

THE BART IMPACT PROGRAM

The San Francisco Bay Area Rapid Transit System (BART) is the first regional rapid transit system built in the U. S. in more than 50 years. It is of great interest as a learning model to the nation's other metropolitan areas which are considering investments in improved transportation and to the Federal government, which is providing financial aid for local transportation improvements, urban development, and environmental protection in urban areas. There is an immediate need for accurate information on the consequences of the BART investment to guide future transportation decisions, both in the Bay Area and throughout the nation.[1]

The BART Impact Program (BIP) is a comprehensive, policy-oriented study and evaluation of the impacts of the new BART systems. The BART Impact Program covers the entire range of potential rapid transit impacts, with major projects covering impacts on transportation systems, travel behavior, land use and urban development, the environment, the regional economy, social institutions and lifestyles, and public policy. The incidence of these impacts on population groups, local areas, and economic sectors is being measured and analyzed. The benefits of BART, and their distribution, will be weighed against the negative impacts and costs of the system in an objective evaluation of the contribution that the rapid transit investment makes toward meeting the needs and objectives of this metropolitan area and all of its people.

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[1] Metropolitan Transportation Commission (1974), A Description of the BART Impact Program, Berkeley: Metropolitan Transportation Commission.

THE ENVIRONMENT PROJECT

The Environment Project fits into the BART Impact Program's overall objectives by focusing on two related phenomena:

- Direct and indirect physical effects upon the environment brought about by the BART system.
- Social and psychological consequences of these physical changes to the environment.

These objectives translate readily into a set of major issues or questions which comprehensively cover the concerns of the Environment Project:

- What aspects of the environment are affected by BART?
- Why do these impacts occur?
- Where do these impacts occur?
- Who are most affected by BART's impacts?
- How can this information be used to inform decision-makers elsewhere?

Several characteristics distinguish the Environment Project as a unique and innovative venture. First, it is a study of an existing transportation system, rather than a planned or hypothetical one. Second, it is geared to seek out whatever environmental impacts exist, rather than be limited to a small set of hypotheses or predetermined impact types. Finally, the project deals not only with the assessment of physical impacts, but also places heavy emphasis on the study of how those persons affected by the impacts respond to them.

Through these features, the Project provides a foundation for major improvements in the forecasting of transit's environmental impacts. In turn, these improvements will enhance the quality of a broad range of public and private decisions in transportation planning, environmental protection, and urban development.

THE PHASE I STUDY

The Environment Project has been divided into two phases. The first, which is the basis of this report, ran from April 1974 to August 1975. The second phase is to run from October 1975 to July 1977.

The major accomplishments of the Phase I work were:

- Development of a detailed Research Plan.
  The Research Plan[1] established the technical approach to be used in the assessment of BART's environmental impacts. It included: major objectives and issues to be addressed; a description of the process by which environmental impacts are assumed to occur; the strategy and methodological approach proposed for achieving the study's objectives; and the initial measurement programs to be used in the assessment of the various types of direct physical impacts.

- Provision of early usable results on BART's physical impacts.
  The Phase I study concentrated on BART's effects on the physical dimensions of the Bay Area and identified the population groups affected by those changes. The documentation of the Phase I work specifically considers what aspects of the environment have been affected by BART; what physical and operational characteristics of BART cause the impacts; where the impacts are occurring; and what are the demographic characteristics of those affected by the impacts.

- Establishment of a baseline for Phase II assessment of changes in impact over time.
  During Phase I, measurements and assessments were made under interim BART operational conditions. In time, these conditions will change (more frequent trains, additional hours of operation), which in turn will affect impacts. In addition, impacts such as sound and vibration may change due to aging or "wearing in" of the system. As these changes occur, new impact measures will be made to determine the new levels of impact as well as the degree of change.

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[1] Gruen Associates, De Leuw, Cather & Company (1975), Environment Project Research Plan, Berkeley: Metropolitan Transportation Commission.

During Phase I, several conditions existed which affected the conduct of the study and the interpretation of the findings presented in this report. These include:

- BART was in an interim stage of operations. As of the end of Phase I, it did not operate at night (no service runs after 8:00 p.m.), nor did it operate on weekends. The frequency of trains was less than full service projections, and patronage was at approximately 60 percent (120,000 riders daily) of predicted full patronage.

- Phase I focused on BART's impacts as experienced by those living and working next to the BART system. It leaves for study in Phase II issues of how these people actually perceive and respond to these impacts; the nature of the encounter of BART patrons with its stations and trains; and "indirect" environmental impacts--those associated with new urban development and travel pattern changes attributable to BART's existence.

- The Phase I study did not include a comparison of BART's impacts with those of any other means of providing public transportation service, such as express bus lines or an expanded freeway system (a "No-BART Alternative"). Phase II will add a corresponding assessment of a "No-BART Alternative's" impacts to provide a balanced view of BART's net effects.

REPORT ORGANIZATION

The major portions of this report concentrate on the identification, measurement and assessment of BART-related direct physical impacts. These findings are reported by individual impact category (e.g., local air quality, noise, safety, etc.). However, related impact categories are consolidated into five groupings--the atmospheric, acoustic, natural, visual and social components of the environment. Each one of these groups forms a separate findings chapter (Chapters 4 through 8).

The two brief chapters following this introduction are offered as a contextual framework for clearer understanding of the specific study findings and how they were obtained. Following the five chapters on findings, the final chapter incorporates the different kinds of BART's environmental impacts into an overall view of the degree, location and causes of impact, as well as the populations affected. A concluding section of that chapter discusses some of the major lessons--or decision-making implications--which have arisen from the Phase I work.

II. STUDY DESIGN

BASIC CONCEPTS

In this study the term environment refers not just to the physical elements of the Bay Area but encompasses a broader set of characteristics organized under a five-component classification of the human environment. These characteristics are referred to as environmental impact categories, and include the following:

Table 5
ENVIRONMENTAL COMPONENTS AND IMPACT CATEGORIES

Environmental Component	Acoustic	Atmospheric	Natural	Social	Visual
Impact Categories	- Sound - Vibration	- Regional air quality - Local air quality - Microclimate	- Biota - Soils and geology - Drainage and water	- Barriers - Safety - Security - Visual exposure	- Visual quality - Illumination - Shadows

These categories were selected through an initial screening of existing environmental impact classifications schemes. Only the categories of potential relevance to a rail rapid transit system were retained.

The term "impact" in this project refers to the effect of a given stimulus, such as the sound of BART trains, on a particular adjacent environment. Environmental impacts can arise directly from BART attributes such as its structural facilities, train and related bus and auto operations, and use of land resources. Impacts may also arise indirectly, through intervening factors such as changes in travel behavior and land use which are themselves due to BART attributes.

The term "response" carries the idea of impact a step further to encompass the varying ways in which different people, in different personal situations, may tend to interpret and react to the impacts which they receive. Determinants of impact influence the occurrence, location or extent of impact. They include characteristics of BART, its environment, and the persons affected.

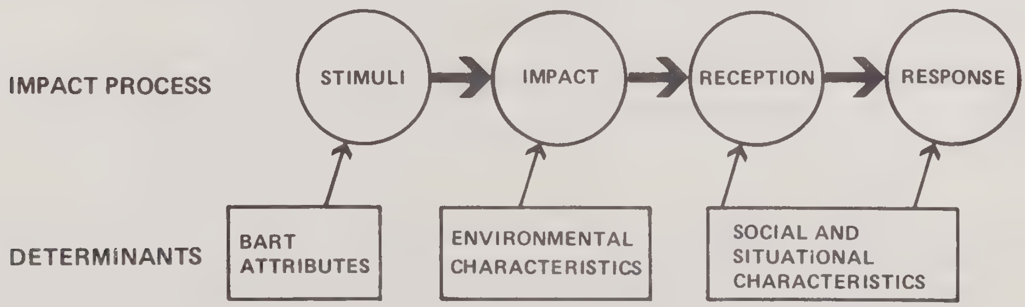
IMPACT PROCESS

The Environment Project not only identifies and assesses impacts but also relates those impacts to their origins and to their effects on people.

In the general model of the impact process used in this study, specific BART attributes (such as station size and train speed) are sources of environmental stimuli (e.g., visual mass and sound). These stimuli interact with characteristics of the nearby environment (visual scale, background sound level) to produce a distribution of impact across a given area. These direct impacts may also give rise to higher-order or indirect impacts.

The impacts in turn are received by persons in the environment, who perceive and respond to them in varying ways. Thus the assessment of impact is not limited to physical measures but includes the study of their human effects as well.

Figure 5
IMPACT PROCESS AND DETERMINANTS



Determinants of environmental impact constitute the inputs into this process. They include origins (primarily BART attributes but also its non-environmental impacts such as changes in travel behavior or land use) and modifiers of impact (characteristics of the surrounding physical environment which influence its susceptibility to impact). Also included are social and situational characteristics of the persons affected. Some of these are age, ethnicity, income and sex, all of which may influence the ways in which people receive and respond to any given impact.

RESEARCH STRATEGY

The assessment strategy focuses first on identification of direct impacts and later on indirect impacts and responses. Site-specific studies are used as a basis for impact estimates for the entire BART system.

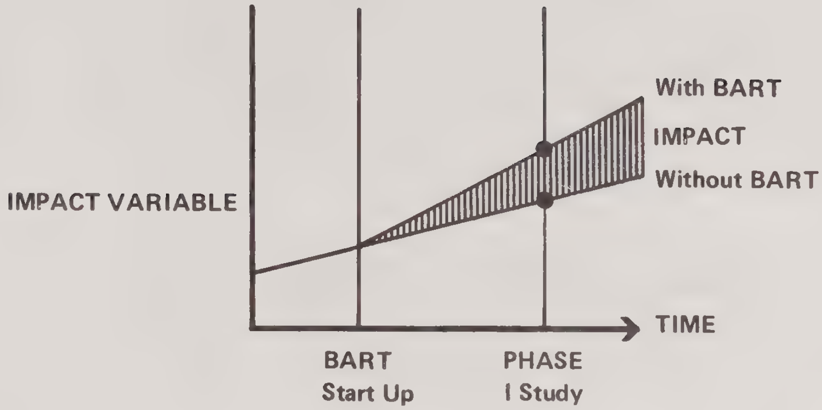
In this initial phase of the Environment Project, the focus was on BART's direct impacts. Effects of specific impact determinants were assessed at sites selected for their representation of the BART system's most characteristic conditions. The occurrence of these conditions throughout the BART system was inventoried, and from this base the overall degree of impact and effect on each determinant was estimated.

In Phase II, the Project's concerns will shift to the human response to these impacts. In addition, studies will evaluate indirect impacts, changes in impacts over time and with changes in BART service, and impacts on BART users. Where a need for further study was identified in Phase I, additional assessments of specific direct impacts will be undertaken.

Environmental impacts are viewed as specific differences between the actual environment--with BART--and a comparable, hypothetical state which might have occurred had BART not been built. At the regional level, this state is termed the No-BART Alternative (NBA), and identification of its main parts is based on a separate study within the BART Impact Program. To be most useful in present-day policy making, the NBA emphasizes realistic current alternatives such as extensive express bus service.

The regionwide BART-versus-NBA impact comparison will be conducted in Phase II. In Phase I, BART's direct impacts were defined relative to a "null" (present-without-BART) situation. This assumes that the NBA would have had no significant effects on BART's immediate environment. Such an approach is complementary to the Phase II NBA impact study since virtually all NBA environmental impacts would have occurred in different places from those of BART. The importance of careful definition of the null or "without-BART" case is illustrated in Figure 6. In this study, several strategies were used. For some impacts, such as sound, it was possible to isolate and measure current BART and without-BART effects directly. For other impacts, historical trends or current conditions in nearby control sites (similar but without BART) were used. Pre-BART versus current conditions were used to define BART's impacts only where historical data and interviews with local officials indicated little or no likelihood of relevant environmental changes since prior to BART if the system had not been built.

Figure 6
ISOLATION OF IMPACTS



Where possible, future as well as present impacts were estimated. This focused on "dynamic" impacts--those most likely to change with anticipated or temporary adjustments in BART service and use. It made use of the Phase I impact findings as well as data on the changes in impact determinants (e.g., BART train frequency and hours) which are expected in the future.

RESEARCH METHODS

The Environment Project's comprehensive and exploratory Phase I approach necessitated that only general research questions be framed to guide the work, rather than specific hypotheses. This allowed broad subject coverage and flexibility to adapt continuously to additional information and interim findings. With the broad base of Phase I findings and data thus developed, Phase II will focus more on the development and testing of hypotheses wherever feasible.

Because of the variety of impacts under study, a broad array of research methods was employed. These included direct observation both on site and from the air, interviews with many local officials and BART personnel, review of published and unpublished statistics and other documentation, instrument measurements, and process modeling. In some cases,

new methods were required even though development of methods was not a major study objective. A particularly innovative approach was developed and used in the assessment of BART's acoustic impacts.

Wherever possible, several independent research methods were used to approach a given research question. For example, in the study of traffic safety impacts around BART stations, approaches included interviews with officials as well as BART station attendants and local patrolmen, direct observation by trained personnel, and study of statistics on traffic accident rates. More detailed explanations of methodology are included in the Findings chapters and in the supporting Technical Memoranda.

In addition to studies of direct physical impact, preliminary indications of public response to BART's impacts were obtained through a program of community monitoring. This included a series of focused group interviews with citizens living and working near the BART system, interviews with local officials, review of media reports and BART complaint files. These were primarily pilot studies for the Phase II response survey.

III. BART DESCRIPTION[1]

BART, which began operations in 1972, is a 71-mile rail rapid transit system that lies within three of the nine Bay Area counties--San Francisco, Alameda and Contra Costa (Figure 7). Within these counties, the system traverses portions of 14 cities, as well as a number of unincorporated areas.

The system is divided into four lines, commonly identified by the names of their terminal stations--Daly City, Richmond, Concord and Fremont, plus a section in downtown Oakland where the lines merge.

In order to acquaint the reader with BART's major environmentally relevant features, this chapter provides a brief description of BART and its surrounding environment. This description first covers BART attributes--its major physical facilities and operational characteristics--then its adjacent physical environment and, finally, some characteristics of the nearby population.

BART ATTRIBUTES: FACILITIES AND OPERATIONS

Configuration

Of the 71 miles of BART right-of-way, approximately 20 miles are below ground in subway, a hard-rock tunnel through Berkeley Hills, and the Transbay Tube across the floor of San Francisco Bay. The remaining 51 miles are above ground on a concrete aerial structure, at grade or on earth embankments of varying heights. (Table 6)

Of BART's 34 stations, 14 are below ground. Ten of these are downtown subway stations, while the remaining four have above-ground mezzanines.

[1] De Leuw, Cather & Company (1976), BART and Its Environment: Descriptive Data, Berkeley: Metropolitan Transportation Commission.

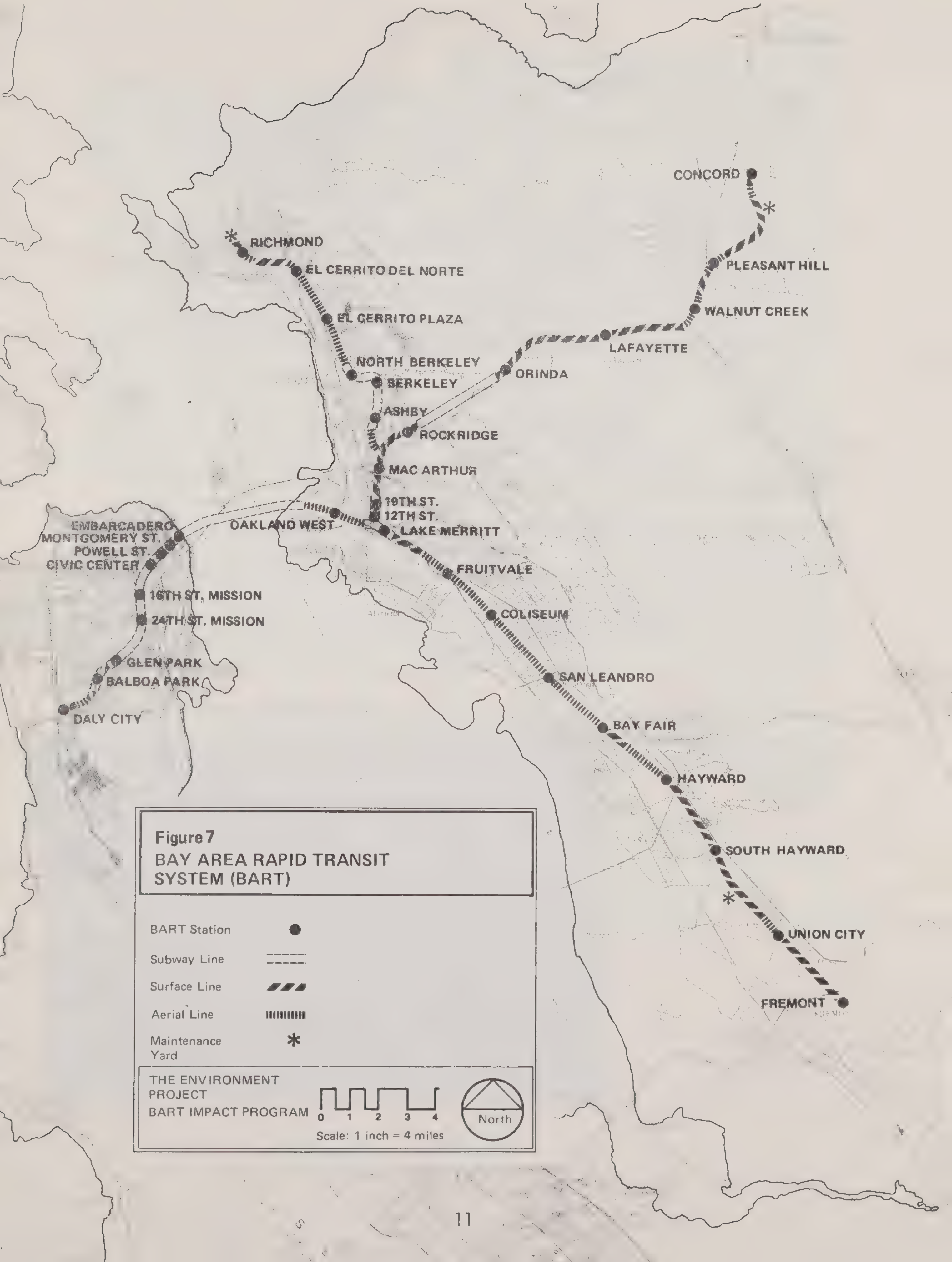


Figure 7
BAY AREA RAPID TRANSIT SYSTEM (BART)

Table 6
BART LINE AND STATION CONFIGURATION

FULL BART SYSTEM 71 miles 34 stations	ABOVE GROUND 51 miles 20 stations	*Aerial* 24 miles, 13 stations
		At-Grade/Embanked 27 miles, 7 stations
	BELOW GROUND 20 miles 14 stations	*Subway* 13 miles, 14 stations
		Trans-Bay Tube 4 miles, no stations
		Orinda Tunnel 3 miles, no stations

BART Parking Lots

Parking lot facilities were built at 23 of the 34 stations, primarily aerial stations in suburban areas. Only one downtown station (Lake Merritt at BART headquarters) has parking facilities. Lot capacities range from 240 spaces to 1,400, covering areas of two to eight acres (up to about four city blocks). Total parking capacity at all 23 stations is approximately 18,000 spaces. Presently, all of the parking facilities are single-level, open lots. There is, however, a multilevel structure under construction at the Daly City station.

Plate 7
BART STATION PARKING LOT—HAYWARD

Trackway Details

BART's lines include a number of features which are potentially relevant to its generation of environmental impacts. These include 93 switch points (technically termed crossovers and turnouts) occurring in groups of one to seven within short distances. All but 10 of these switch points are above ground.

BART lines cross 31 bridges (each of which is over 200 feet in length), in addition to its aerial lines. These typically involve a sudden change of configuration from embankment to an elevated (bridge) structure. There are also a number of horizontal curves along the lines, but virtually all are of very long radius and superelevated for BART's operating speeds. Finally, there are 15 tunnel or subway portals.

Landscaping

Landscaping was used in varying intensities and styles at all surface stations. In general, such landscaping was not extensive and consisted primarily of low-maintenance ground cover and small trees.

A significant departure from this approach is found in the 2.7-mile linear park which extends along the aerial track through the cities of Albany and El Cerrito. Here landscaping was extensive, in an experimental effort to offset the anticipated adverse impacts of the aerial trackway. A similar, although less extensively landscaped 0.5-mile section is found in Concord.

Patronage

During the first half of 1975, the BART system was carrying 115,000 to 120,000 one-way trips per day (i.e., 60,000 round trips). Average p.m. peak-hour patronage was approximately 35,000. The projected full, daily one-way patronage is 200,000.

Station patronage varied from 2,000 (West Oakland) to 42,000 (Montgomery Street in downtown San Francisco). Suburban station daily patronage was generally in the range of 3,000 to 6,000 pass-throughs, or 1,500-3,000 round-trip patrons. The stations of highest activity are located in downtown San Francisco, Oakland and Berkeley; in these areas, six stations account for approximately 45 percent of the total average daily activity.

Train Speed and Frequency

The maximum design and operational speed for the BART system is 80 mph. The current normal train speed under Automatic Train Control (ATC) averages under 40 mph for approximately 30 percent of the system; 40 to 60 mph

for 25 percent; and over 60 mph for the remaining 45 percent of the system. Train length varies from a minimum of two cars to ten cars, with each car capable of seating 72 passengers. At present, mainly six- to nine-car trains are used; some ten-car trains are used during peak periods.

Table 7 presents train frequency statistics for current (weekdays, 6:00 a.m. to 8:00 p.m.) and ultimate conditions in terms of peak and non-peak period headways.

Table 7
TRAIN FREQUENCY (HEADWAYS)

	Current (Weekday Only)		Ultimate			Ultimate Weekend	
BART Line	Peak (Minutes)	Non-Peak (Minutes)	Peak (Minutes)	Weekday Non-Peak Til 10 pm (Minutes)	10 pm -1 am * (Minutes)	5 am -10 pm * (Minutes)	10 pm -1 am * (Minutes)
Fremont	6	6	3	6	20	15	20
Concord	12	12	6	12	20	15	20
Richmond	12	12	3	6	20	15	20
Daly City	6	6	2	4	20	15	20

* Source: BART memo dated September 9, 1974, BART Planning Office personnel.

ADJACENT ENVIRONMENTAL CHARACTERISTICS

BART's four lines radiate outward from the dense Oakland-San Francisco urban cores. All lines traverse older areas of medium-density residential and industrial uses. Two (Concord and Fremont) of the four lines extend several miles into newer low-density suburbs.

Land Use

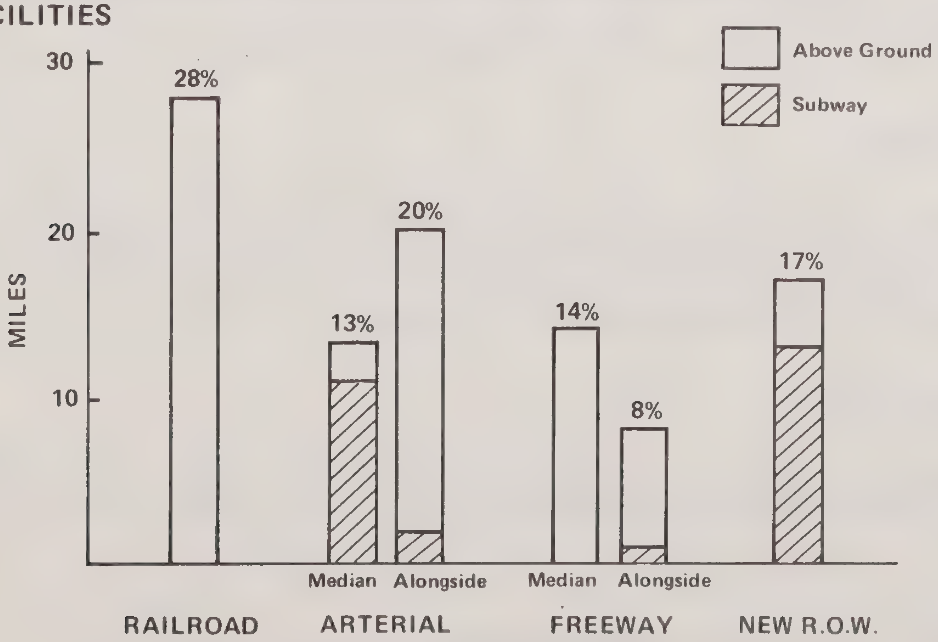
Of BART's 71 miles, approximately 77 percent or 55 miles are adjacent to predominantly residential uses; the balance, 23 percent or 16 miles are adjacent to non-residential (industrial, commercial, vacant, etc.) uses on both sides of the track. Of the system's 51 miles above ground, 44 miles are in residential areas.

Plate 8
BART ON AERIAL TRACKWAY IN A RESIDENTIAL AREA—ALBANY

Adjacent Transportation Facilities

Nearly 85 percent of the BART right-of-way is within or alongside the right-of-way of another major transportation facility. Figure 8 displays the proportion of each type of adjacent transportation facility along the entire BART system. Railroad rights-of-way account for the largest proportion of adjacent transportation facilities.

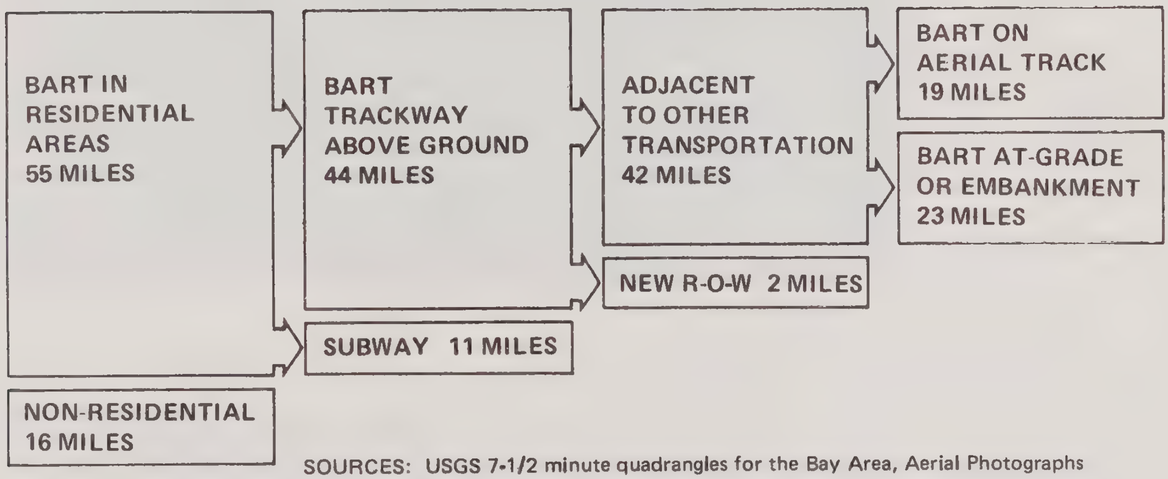
Figure 8
PROPORTION OF BART ADJOINING OTHER TRANSPORTATION FACILITIES



Sources: USGS 7½-minute Quadrangles for the Bay Area; BART Impact Aerial Photos (1972 Series).

Because above-ground configurations are of greatest interest in terms of impact potential in predominantly residential areas, adjacent transportation facilities are summarized for these areas in Table 8.

Table 8
ADJACENT TRANSPORTATION FACILITIES IN RESIDENTIAL AREAS



SOURCES: USGS 7-1/2 minute quadrangles for the Bay Area, Aerial Photographs (1972 pre-BART Series), BART Track Charts ("as-built" drawings).

SOCIAL AND SITUATIONAL CHARACTERISTICS: THE POPULATION NEAR BART[1]

The three-county area in which BART is located contains a total population of approximately 2,400,000. About 1,000,000 persons live within one mile of the system, and nearly 70,000 are in the census blocks nearest BART.

Population Density

Of the 55 miles of the system which are in residential areas, nearly 60 percent are in medium-density areas (21 to 60 persons per acre). The Daly City line has the greatest proportion of high-density residential areas next to BART, while the Concord line has the lowest.

Median Family Income

The percentage of population with incomes less than $7,000 is somewhat higher in the immediate area surrounding BART than in the counties in

[1] Source: 1970 U. S. Census of Population.

which the lines are located. The one exception to this is the Concord line in which the percentages are similar. However, on all lines, only a small proportion of the mileage is populated predominantly by low-income families.

Ethnicity

There are significant numbers of blacks (20 percent of the population in the census tracts nearest BART) and individuals of Spanish heritage (nearly 16 percent) along the BART system.

Elderly

As with ethnic minorities and low-income families, the area around the BART system has slightly higher concentrations of elderly (65 years or older) than the entire three-county area. In several small areas, mainly along the Daly City and Concord lines, over 30 percent of the residents are older than 65.

IV. BART IMPACTS ON THE ACOUSTIC ENVIRONMENT[1]

INTRODUCTION

The acoustic environment is defined to include both sound and vibration. BART is a dynamic mechanical system, generating both sound and vibration; as such, it can add to the level and variety of the acoustic environment.

The Phase I acoustic study concentrated on the sound impacts of BART trains and involved extensive instrument measurements and statistical analyses. Lesser emphasis was placed on vibration caused by the trains and sound and vibration caused by feeder buses and autos. The preliminary studies of these secondary topics will be expanded as required during Phase II.

SOUND

BART's impacts on community sound levels focused on several key topics:

- Prior community sound levels along BART lines
- Location and intensity of present impacts
- Nature and location of likely future changes
- Major and other contributory causes of impacts
- Comparison of BART's actual impacts with original predictions and other travel modes

Methodology

In order to provide a systemwide sound impact assessment, an innovative approach was developed and applied. Its key features, discussed in subsequent sections, are as follows:

- Definition of sonic impact
- Selection of impact measures

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[1] Bolt Beranek and Newman Inc. (1976), Acoustic Impacts of BART - Interim Service Findings, Berkeley: Metropolitan Transportation Commission. References in this chapter to a Technical Memorandum (TM) refer to this document.

- Estimation of background community sound levels

- Measurement of BART sound levels

It is a characteristic of sound that when one sound is joined by another of equal intensity, the resultant increase in intensity is barely perceptible. This effect applies to a steady sound. By extension, it is taken to apply also to two independently varying sound sources whose averages over time are equal. In order for the second sound to have a significant impact, it must be substantially more intense than the original or "background" sound. Thus sonic impact, as defined in this study, occurs when the sound generated by BART exceeds the existing level in the community.

There is continuing controversy over the selection of measures appropriate for assessment of transit's sonic impacts. Instantaneous or maximum sound level--the loudest sound reached by a passing train--could be used. However, this would not consider how often the trains pass, or how sound might vary from one train to another. In addition, background community sound intensity also varies, for example, through noise of construction, motorcycles, trucks and sirens; thus sound measures should be consistent between BART and community sound if the results are to be meaningful. For example, it would be misleading to rely on comparison of BART's maximum sound with an average community sound. On the other hand, use of averages for both BART and community sound levels tends to mask the actual momentary effect of the passage of a BART train.

Obviously there is no "best" approach. For this study's purposes, a standard measure, the hourly "equivalent sound level" (L_{eq}), was selected for BART sound based on its prior use in railway freight and aircraft takeoff noise assessment (TM, pp. 63-64). This measure yields an average hourly sound intensity due to BART train pass-bys only.

As a basis for comparison, corresponding community sound levels were measured with the "daytime equivalent sound level" (L_d). This is a logarithmic average (TM, pp. 63-64) of the hourly L_{eq} values due to factors other than BART; it serves to remove the effect of hour-to-hour variations in community sound during BART's current (daytime) hours of operation (TM, p. 64).

Community sound levels systemwide were estimated first using recently-identified relationships between population density, traffic levels, and resulting sound levels.[1] These were verified by 24-hour sound measurements at 12 points throughout the system (TM, pp. 8-20).

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[1] M. A. Porter, W. E. Blazier, and D. M. Schwartz (1974), Noise In San Francisco, San Francisco: Bolt Beranek and Newman Inc.

BART sound levels were established in a similar two-part measurement program. First, train sound level variations were recorded on board trains running throughout the BART system. This "sound profile" by location was then adjusted to actual wayside dB(A) values[1] through a program of wayside measurements of BART train pass-bys at some 15 points throughout the system (TM, pp. 51-59).

Issues and Findings

What are the community sound levels along the system when BART is not operating?

The wayside communities along BART range from densely populated residential and commercial/residential areas such as Daly City and Albany-El Cerrito to relatively sparsely populated suburban residential communities such as found in Pleasant Hill, Walnut Creek and Fremont. However, adjacent to virtually all of the BART system are other major transportation arteries such as freeways, major arterial streets, and railroad lines. With the exception of the portion of the system near Fremont and Union City, where BART is above ground and runs near low-density residential areas, at least one other major transportation artery parallels the BART tracks. This indicates that, for the most part, BART does not run in areas otherwise classifiable as "very quiet." This was supported by available statistical relationships and field measurements which yielded a range of L_d values of 55 to 70 dB(A) in communities alongside the system (TM, pp. 4-20).

What is BART's present impact on community sound levels?

At a distance of 50 feet from the track centerline, the hourly equivalent sound level (L_{eq}) generated by BART was found, depending upon the location, to range from below the community sound level (L_d) maximum of 12 dB above it. At a distance of 250 feet from the tracks, the BART-generated sound level (L_d) did not exceed the community sould level by more than 4 dB in any location.

Houses further removed from the BART system are generally shielded from BART-generated sounds by the first row of houses or other buildings adjacent to the BART line. Because of this factor, the acoustic impact of BART is generally confined to an area that extends substantially less than 250 feet away from the BART system. In fact, in most situations, the impact is most likely limited to only the first row of houses or other structures along the system.

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[1] Sound intensity measure with frequency distribution weighted to reflect human perception (TM, pp. 62-63).

The relationship between the L_{eq} (generated by BART) and the range of L_d in the community is illustrated on Figure 9. Shown are the L_{eq} values that currently exist at a distance of 50 feet from the centerline of the track along the BART system. Additionally, the range of the mean L_d levels in the communities adjacent to the BART system is indicated by the shaded band. The protrusion of the line indicating BART sound above the community band indicates that a perceptible impact may be occurring. The higher the BART levels protrude above the community levels, the greater the likelihood of impact.

<u>Possible</u> acoustic impact (defined as BART L_{eq} exceeding community L_d by not more than 5 dB) is expected along approximately 30 percent of the total BART system; along 10 percent of the system, acoustic impact is considered <u>probable</u> (defined as BART L_{eq} exceeding the community L_d by more than 5 dB). Population figures from the 1970 census data indicate that approximately 15,000 people live within the census blocks adjacent to BART in both affected regions (TM, p. 40).

<u>How is this impact likely to change with BART's planned future addition of evening service and more frequent daytime trains?</u>

The impact just described is based on existing conditions (daytime operations, headways of 6 or 12 minutes). Future plans for BART indicate that both train headway and hours of operation may be expected to change. The reduction of headways from 6 minutes to 2 minutes would result in an increased L_{eq} of approximately 5 dB (TM, p. 40). This would mean that rather than at a few locations, the BART-generated L_{eq} may be expected to exceed the community L_d by 10 dB along much of the system located in residential areas.

Late night and early morning sound levels in the community tend to be on the order of 8 to 10 dB below the daytime levels (TM, p. 41). Thus, nighttime BART operations will be much more evident in the community. Even with 20-minute headways, as have been projected for some of the late night operations, wayside BART L_{eq}'s of 62 dB(A) at a distance of 50 feet from the centerline of the track are expected. Assuming that the community sound levels will drop by 10 dB during the late night hours, the L_{eq} of nighttime BART operations could well be on the order of 15 dB or more above the community nighttime equivalent sound level (L_n).

<u>What aspects of BART's operation are the main causes of these sound impacts?</u>

Many individual factors contribute to the sound levels generated by the BART system. A significant portion of this study was devoted to identifying the more important of these factors. Three primary factors affecting wayside

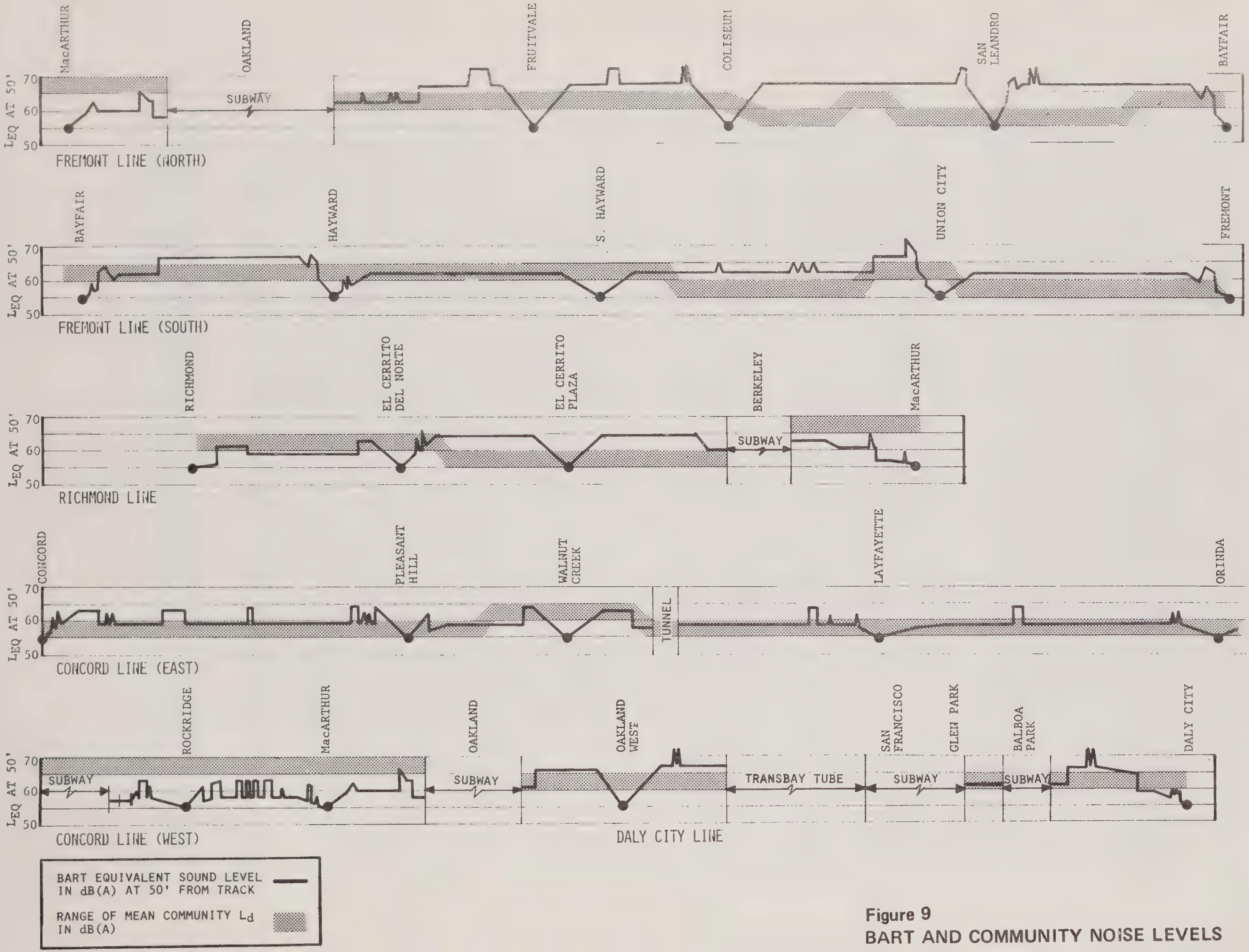


Figure 9
BART AND COMMUNITY NOISE LEVELS

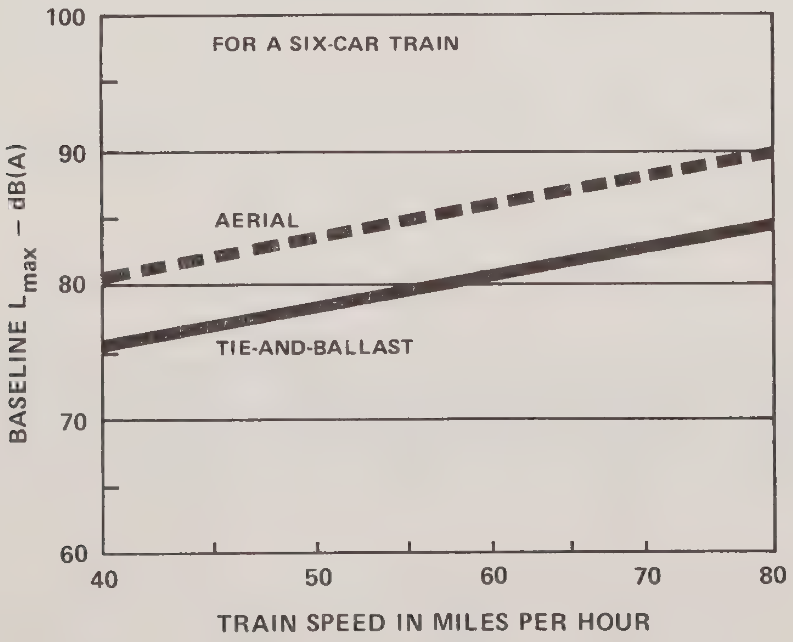
sound levels were identified: train speed, track configuration and switches (TM, pp. 20-29). Of these, train speed was found to have the greatest range of effect. The maximum A-weighted sound level (L_{max}) at the wayside of the BART system was shown to be proportional to 28 $\log_{10}$ of the train speed. This dependence on speed indicates that the wayside L_{max} will vary approximately 8 dB from the locations having the lowest average operational speed on the system (36 mph) to those with the highest average operational speed (70 mph).

The track configuration--concrete aerial structure versus at-grade (tie and ballast)--was also found to have a significant effect on sound generation. For trains traveling at equal speeds, the L_{max} adjacent (50 feet) to tie-and-ballast track is approximately 5 dB lower than the L_{max} adjacent to track on aerial structures.

The relationship between train speed, track configuration and wayside sound level is indicated for a six-car train by Figure 10. The figure shows that for a train traveling 65 mph on tie-and-ballast track, the projected L_{max} would be 82 dB(A). For a train operating at the same speed on aerial structure, the L_{max} would be 87 dB(A).

Figure 10

BART MAXIMUM SOUND LEVEL (L_{max}) AS A FUNCTION OF TRAIN SPEED AND TRACK CONFIGURATION



On either type of track, the presence of a switch (turnout or crossover) results in an additional 5 dB increase in the wayside L_{max} in the immediate area.

What other factors also affect the wayside sound levels of BART trains?

The wayside sound levels along the BART system exhibit variations which cannot be attributed to train speed, track type or switches. Some of these variations are due to the differences in sound levels produced by individual trains (TM, p. 22). The standard deviation of the L_{max} of individual trains about the mean L_{max} for all trains is approximately 1.5 dB. This variation indicates that some 90 percent of the vehicles on the BART system will produce wayside L_{max} values within ± 3 dB of the mean. (Further analysis will be done in Phase II to provide information on the effects of aging and maintenance).

The first row of houses or other buildings adjacent to the BART line tend to shield those residences further removed from the system from BART-generated sounds. The shielding offered by the first row of structures is on the order of 5 to 10 dB (TM, p. 23). Where the houses are fairly close together (as is typical in the Bay Area), the degree of shielding would tend to be nearer the 10 dB value than the 5 dB value.

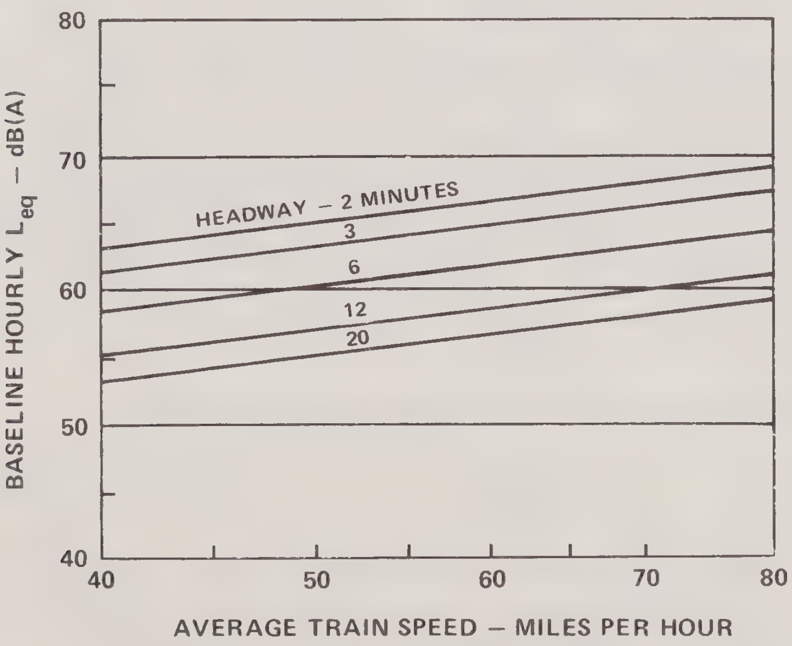
The median L_{max} observed adjacent to curves with a radius of less than 4,500 feet tended to be approximately 5 dB higher than was observed adjacent to straight track. Since this tendency was noted only for approximately half of the vehicles observed (no correlation was found between vehicle speed and the vehicles exhibiting higher sound levels), these findings must be considered at best tentative. Furthermore, an increase in the L_{max} was observed adjacent to several portions of curved track where the radius was considerably in excess of 4,500 feet. Subjective observation of these increased levels indicates that a factor accounting for the acceleration or deceleration of the train through the curve may also affect wayside L_{max} (TM, pp. 29-30).

No significant increase in the L_{max} created by BART pass-bys was observed in the vicinity of tunnels. The reverberation of sound within the tunnel and subsequent release of this sound energy to the atmosphere at the tunnel entrance, however, did increase the amount of time which the sound level remained within 10 dB of its maximum. Thus, due to the longer duration of the sound, the L_{eq} was increased (TM, p. 30).

In general, it was found that the sound generated by automobile traffic into and out of the stations was virtually lost in the background of other vehicular operations in the community. A similar finding was reached for BART feeder bus traffic. That is, the sound levels generated by buses at the BART stations were less than or equal to sound levels already present on the arterials near BART stations due to other transportation sources (TM, pp. 30-31).

Figure 11 is used in a manner similar to Figure 10, but shows equivalent sound level (L_{eq}) rather than maximum sound level (L_{max}). For similar operating conditions, such as a six-car train traveling 65 mph on tie-and-ballast at six-minute headways, the L_{max} would be 82 dB(A), whereas the L_{eq} would be 62 dB(A). The data on Figure 11 indicates how the L_{eq} values vary as a function of different train speeds and headways.

Figure 11
BART EQUIVALENT SOUND LEVEL (L_{eq})
AS FUNCTION OF TRAIN SPEEDS AND HEADWAYS



NOTE: These sound levels include the effects of BART trains traveling in both directions at the headways stated.

Table 9 lists corrections that can be applied to Figure 11 to account for differences in configuration and train length. For example, the L_{eq} for eight-car trains operating at 65 mph, at six-minute headways, over a switch on an aerial section, would be 62 + 1 + 5 + 5 = 73 dB(A).

Table 9
CORRECTIONS TO BASELINE L_{eq}

Condition	dB(A)
Tie and ballast (berm or grade)	+0
Aerial structure	+5
Switch on berm or grade	+3
Switch on aerial	+5
Curve (radius < 4,500')	+5
2-car train	−3
4-car train	−1
6-car train	+0
8-car train	+1
10-car train	+2

How do BART's sonic impacts compare with those of buses and autos?

Using the data on BART and a highway traffic model developed for the Highway Research Board[1], the following table was developed to illustrate the sound levels for three different transportation modes conveying 7,000 passengers per hour (BART's nominal capacity) past a given point.

Table 10
COMPARISON OF BART AND OTHER TRANSPORTATION MODES

Transportation Mode	Conditions	Sound Level (L_{eq}) @ 50' from Noise Source
BART	10 trains (10 cars each, 6-minute headways) 70 mph	70 dB(A) Aerial 65 dB(A) Tie and Ballast
Passenger cars	4,600 vehicles (1.5 passengers/vehicle) 45 mph	73 dB(A)
Commute buses	150 buses (45 passengers/vehicle) 45 mph	71 dB(A)

[1] C. G. Gordon, W. J. Galloway, B. A. Kugler, and D. L. Nelson, (1971), Highway Noise: A Design Guide for Highway Engineers, National Cooperative Highway Research Program Report No. 117, Los Angeles: Bolt Beranek and Newman Inc.

The differences in sound between BART in an aerial configuration and the other two modes is not appreciable. However, BART trains operating on tie-and-ballast (at grade or embanked) track are found to be significantly quieter than autos or buses carrying the same volume of passengers per hour.

How does actual BART-generated sound compare with earlier expectations based on measures of prototype cars?

Significant differences between prototype and operational systems are often encountered. The close control exercised over prototypes during the initial testing stages is often impractical for full-scale operational systems. Therefore, the degree to which the operational BART system performs as was projected from prototype measurements is of importance in the establishment of confidence limits on projections for future transit systems.

In a report prepared for BART,[1] projections were made concerning the wayside sound levels that might be expected due to BART operations. These projections were made on the basis of a series of measurements of prototype BART vehicles operating on the initial aerial test track. This report indicated that at a distance of 50 feet from a train on an aerial structure at 70 mph, a wayside L_{max} of 87 dB(A) might be expected. This projected level is indeed the same as has been found for the mean L_{max} due to the operation of six-car trains on aerial structures. The 1969 report, however, indicated that the expected wayside L_{max} adjacent to tie-and-ballast track would be only 2-3 dB quieter than the L_{max} of aerial track. However, this study indicated a 5 dB difference exists between aerial and tie-and-ballast track.

VIBRATION

The primary goals of the vibration-related portion of the study were to examine the likelihood of community impact due to BART train-generated vibrations and to gather baseline data for later (Phase II) assessment of BART train aging and maintenance effectiveness.

Methodology

No significant vibration impacts were expected to be found, in view of BART's observably smooth riding characteristics and the general lack of available evidence of community concern on this topic. Consequently, the

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[1] G. P. Wilson (1969), Wayside Noise Levels to be Expected from Operation of the Bay Area Rapid Transit System Trains, Berkeley: Wilson Ihrig and Associates, Inc.

Phase I study was simple in design in comparison with that of the sound impact study: ground-borne vibrations were monitored by instrument at two sites, one with BART in a typical aerial format and the other a subway. Monitoring periods of several hours and approximately 35 train pass-bys were used, in order to assure data representative of a variety of BART vehicles (TM, pp. 41-43, 58-60).

Issues and Findings

What wayside vibration effects are caused by BART trains operating in subway and aerial configurations?

Vibration measurements on a structure above the BART subway line (Mission Street in San Francisco) indicated that the more prominent of the BART pass-bys could be identified and separated from other vibrations caused by vehicular traffic. The overall vibration velocity level in the 5-50 Hertz (Hz)[1] region was not noticeably greater for BART pass-bys than for vehicular traffic on the street above. The vibration velocity levels seldom, if ever, exceeded what is commonly considered the threshold of sensory reaction to vibrations.

Vibration levels measured near the base of an aerial structure in a residential area showed a marked increase during the pass-by of each BART vehicle. The overall vibration velocity level tended to rise on the order of 15-20 dB above the ambient as BART vehicles passed by. These BART pass-by levels measured were of the same order of magnitude as those caused by delivery trucks operating in the neighborhood on an adjacent street.

The overall vibration velocity levels measured at both locations were dominated by components in the 16-20 Hz and 25 to 35 Hz ranges. The components in the lower range correspond to wheel rotational frequencies of the train wheels. "Flat spots" on wheels may account for this. The source of the higher frequency component is less certain.

The magnitudes of the BART-induced vibration levels at both measurement locations were nearly the same as peak levels due to vehicular traffic on the adjacent streets. The magnitudes of the vibration input of street vehicles at both locations are very nearly the same. This indicates, at least qualitatively, that the level of BART-induced vibration is of the same order of magnitude at both locations.

Vibration effects of rapid transit systems are most often considered as being a problem near subway portions of such systems. Ground-borne

[1] Hertz (Hz) refers to cycles per second.

vibrations in the community near aerial structures have commonly been considered to be of less significance. This study's initial findings appear to contradict this presumption. To verify these findings, the vibration study will be extended through further measurements and analysis in Phase II.

V. BART IMPACTS ON THE ATMOSPHERIC ENVIRONMENT[1]

INTRODUCTION

The atmospheric environment for purposes of this study is described by the impact categories of local and regional air quality and microclimate. Assessment included effects on regional air pollutant emissions, station-area carbon monoxide (CO) emissions, and changes in wind direction and velocity.

REGIONAL AIR QUALITY

One of the possible consequences of a rapid transit system such as BART is to divert people from autos to transit, and thus reduce the number of vehicle miles traveled (VMT). As a result, the region's levels of automobile-generated air pollutants decrease. These include carbon monoxide (CO), reactive hydrocarbons (RHC), and oxides of nitrogen (NO_x).

However, BART is not a pollution-free mode of transportation. The entire system requires electrical energy in order to function, and the power plants supplying that energy emit air pollutants. Thus, to properly assess BART's influence on changing air quality in the San Francisco Bay Area, it was necessary to consider both the reduction in automotive emissions and the increase in emissions due to power plants supplying BART's electrical energy.

Methodology

BART's impact on automobile emissions was computed to be approximately proportional to the reduction in VMT caused by the shift of travelers from autos to BART. This required estimates of several factors, including total vehicular pollutant emissions for the region, total regional VMT, and the BART-induced VMT reduction.

Total regional emissions were calculated for 1972, the last year before BART began operations, because this was the latest year for which the detailed auto age and type data required were available. These data were used in a model based on Federal Environmental Protection Agency procedures, the Vehicle Emissions Model (VEM), yielding emission factors in grams per mile for CO, RHC, and NO_x (WP, pp. 10-15).

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[1] TRW, Inc. (1976), Impacts of BART on Air Quality - Interim Service Findings. Berkeley: Metropolitan Transportation Commission. References in this chapter to a Working Paper (WP) refer to this document.

These factors were multiplied by the estimated regional VMT for 1972 to produce estimates of total vehicular pollutant emissions for the region. The regional VMT was estimated by interpolation from MTC model projections for 1970 and 1980 (WP, p. 16).

In estimating BART's impact on VMT, the system's projected ultimate patronage of 200,000 riders per day was used. This figure was adopted in lieu of the present interim-service patronage in order to allow an estimate of BART's maximum rather than interim effect on travel. This was translated into total BART traveler mileage by multiplying by trip lengths from BART station-to-station projections. Adjustments were applied for the proportion of BART travelers diverted from autos (from BART traveler surveys) and auto occupancy. The resulting maximum BART-induced VMT reduction was approximately 3 percent.[1]

This 3 percent reduction was applied to the 1972 regional emissions estimates to produce the desired estimates of emissions reductions attributable to BART. Given the several assumptions involved, these estimates are conservative; that is, actual 1975 emissions reductions are substantially smaller, and future reductions are very unlikely to be higher than these figures.

Issues and Findings

What is BART's impact on reducing regional air pollutant levels?

BART's diversion of auto users to transit has resulted in some, but a relatively small, decrease in auto-generated air pollutants. For the three counties (San Francisco, Alameda, Contra Costa) in which BART operates, based on the estimated 3 percent BART-induced reduction in VMT, a 3 percent reduction in emission of reactive hydrocarbons, carbon monoxide and oxides of nitrogen would be achieved.

For the entire nine-county Bay Area airshed, the estimated influence of BART on VMT and emissions was even smaller, amounting to less than 1.5 percent of the regionwide emissions.

[1] The VMT reduction was based on a total daily VMT of 25,153,000 for the three-county BART service area. The estimated average weekday reduction in VMT represented by projected BART ridership diverted from autos is 861,800. Thus, the percent reduction if BART had been running at its full service level in 1972 would be 861,800/25,153,000 or 3.4 percent (WP, pp. 16-19).

These percent reductions translate into the following quantities of reduction in pollutants:

CO: 32 tons per day

RHC: 5 tons per day

NO_x: 4 tons per day

One way of viewing the effect of the estimated reductions is to relate them to the goals of EPA's required emission reductions (to achieve the National Ambient Air Quality Standards) as called for in the Control Strategy for the San Francisco Bay Area.[1] The numbers indicated in Table 11 apply to mobile sources only in the three-county area in which BART operates.

Table 11
RELATIONSHIP OF BART-INDUCED POLLUTANT REDUCTIONS TO EPA-REQUIRED REDUCTIONS

Pollutants Produced		EPA-Required Reductions		BART-Induced Reductions	
CO	1,073 tons/day	*CO*	504 tons/day	*CO*	32 tons/day
RHC	168 tons/day	*RHC*	131 tons/day	*RHC*	5 tons/day
NO_x	141 tons/day	NO_x	None required	NO_x	4 tons/day

Clearly, BART's positive impact on regional air quality has been small. In contrast, it is interesting to note that in the Pre-BART Studies (REIS),[2]

[1] TRW, Inc. (1973), Air Quality Implementation Plan Development For Critical California Regions: San Francisco Bay Area Intrastate AQCR, Washington, D.C.: Environmental Protection Agency.

[2] D. Appleyard, F. Carp et al (1973), Residential Environment Impact Study (Part II, Volumes I-VI), BART II: PRE-BART STUDIES OF ENVIRONMENT, LAND USE, RETAIL SALES, Berkeley: Institute for Urban and Regional Development for the Metropolitan Transportation Commission.

one of the questions posed to those being interviewed related to the expected effect BART would have on air pollution. Nearly 65 percent of the respondents felt BART would result in less air pollution. This was one of the few questions related to expected environmental impact in which there was a strong positive expectation.

Has BART been responsible for increasing regional pollutants as a result of its energy requirements?

BART's contribution to air pollution, resulting from the power sources required to satisfy its electrical consumption, is negligible. The analysis of energy impact within the Environment Project focused only on regional air quality implications. A fuller analysis of BART's energy-related impacts was done in the Transportation System and Travel Behavior (TS & TB) project.[1] As such, the intention here is to give only a general idea of the order of magnitude of emissions attributable to BART's energy demands and then to compare these with BART's induced emission reductions.

The major factors used to derive the quantity of power plant emissions attributable to BART electricity demands included (WP, pp. 5-6):

- Total Bay Area consumption of electricity
- BART's electricity usage
- Power plant emissions in the Bay Area

It should be noted that the analysis was based on several assumptions, all of which affect the representativeness of the numbers obtained. Among the most important of these assumptions were:

- Emissions from Bay Area power plants are equally attributable to the electricity demands of all users, including BART
- Emissions are proportional to power production

[1] Peat, Marwick, Mitchell & Co. (1975), Analysis of BART's Energy Consumption for Interim System Operations, Berkeley: Metropolitan Transportation Commission.

Based on these factors and the forecasted BART energy consumption for the full system service,[1] the total system energy for BART would be responsible for the following quantities of pollutants:

CO:	13 lbs/day
RHC:	96 lbs/day
NO_x:	2,430 lbs/day

Though BART's net effect on pollutants (production versus reduction) is small in absolute numbers, the reductions due to VMT changes are far greater than the production due to increased electrical energy demands.

Table 12
BART-INDUCED POLLUTANT REDUCTIONS AND PRODUCTION

Pollutant	BART-Induced Reduction	BART-Induced Production
CO	– 64,000 lbs./day	+ 13 lbs./day
RHC	– 10,000 lbs./day	+ 96 lbs./day
NO_x	– 8,000 lbs./day	+ 2,430 lbs./day

The numbers shown in Table 12 are estimates based on several assumptions as already described. Even allowing for considerable variation from these figures, however, they clearly indicate the very large net differences between BART's induced reduction and generation of pollutants.

LOCAL AIR QUALITY

This portion of the atmospheric impact study consisted of an evaluation of the influence of BART-induced motor vehicle traffic on ambient air quality

[1] As with the VMT reduction data, 1972 numbers for total net production in Northern California and power plant emissions were used. The basis is therefore the same in both cases.

in the immediate vicinity of BART stations with parking lots and within the parking lot itself. The former focused on the resident next to BART, the latter on the BART user.

Pertinent issues which were explored in this phase of the study were:

- The nature and intensity of the impact of BART-induced motor traffic on ambient air quality

- The relationship between various attributes of BART stations (capacity, occupancy, congestion, etc.) and air quality

Methodology

For the purposes of this study, local air quality is defined as the ambient air quality in and around BART stations and adjacent areas. Motor vehicle emissions from BART-induced traffic were expected to influence levels of various pollutants in the immediate vicinity of the BART stations. These pollutant types include hydrocarbons, sulfur dioxide, nitrogen oxides, particulate matter, lead, carbon monoxide, and other gases of less significant concern. It was not immediately clear which atmospheric pollutant would be most affected by changes in motor vehicle travel patterns. However, the cause-and-effect relationship between carbon monoxide (CO) concentrations and their origins is known more clearly than that involving other less stable pollutants and their sources. Because of this, CO was selected as the indicator of local air quality.

As it was not practical to provide an analysis for each of the BART stations, it was necessary to select study sites which typify BART station attributes of particular interest in the study. Accordingly, two BART stations were selected as being representative of local extremes with respect to intensity of impact origins (heavy and light BART-induced motor vehicle traffic). The two BART stations selected for study are the North Berkeley station (low patronage, small parking lot) and the Hayward Station (high patronage, large parking lot, large traffic volume). Both of these sites are removed from any intense non-BART CO sources such as freeways or industrial manufacturing operations, permitting an analysis of cause and effect without major confounding influences.

The concentration of carbon monoxide in the ambient air was measured using a strip chart recorder connected to an Ecolyzer. Air quality was measured for a one-day period at both the North Berkeley and Hayward stations. Three locations at both stations were monitored: the BART station and parking lot downwind from the station (neighborhood site), and upwind from the station (control sites). Measurements at station and neighborhood sites were

conducted to provide an indication of the influence of BART on local ambient air quality. Measurements at the control sites were performed to provide a characterization of the baseline ambient air environment--what the station and neighborhood air quality would be if BART were not present (WP, pp. 70-71).

Issues and Findings

What impact does BART have on local air quality within its parking lots?

The hourly concentrations of CO in BART parking facilities are relatively low and well within the 35 ppm[1] hourly limit allowed by the National Ambient Air Quality Standards. The highest level of CO measured at the two BART stations was recorded during the morning sampling period at the North Berkeley Station. Particularly stable atmospheric conditions permitted CO buildup during the morning heavy traffic activity, and an hourly high of 10.5 ppm (in both the parking lot and station entrance) was reached in the final hour of monitoring. The greatest hourly concentration of CO recorded at the Hayward Station was measured as 8 ppm at the station entrance in the morning (WP, pp. 39-40).

BART patrons entering the station from the parking lot are subjected at times to short term (a few minutes) higher exposures of CO (up to 23 ppm). This is due to intermittent congestion in the parking lot causing high levels of CO emissions with subsequent high short-term localized CO concentrations.

How does BART impact air quality in the vicinity of BART stations?

The impact of BART-induced motor vehicle traffic on ambient air quality in the vicinity of the BART stations (adjacent neighborhood and control sites) is relatively minor. It is not appreciably different than would have been expected in the same location if BART did not exist.

Measurements indicated significant variations of CO levels within individual control (upwind) sites. These variations were related to CO source activity (amount of traffic on adjacent streets) and atmospheric conditions (prevailing wind strength). The peak hourly values of CO measured at the control sites varied from 2.0 to 8.5 ppm at the Hayward locations. At the North Berkeley locations the levels varied from 1.0 to 12.5 ppm (WP, pp. 35-39).

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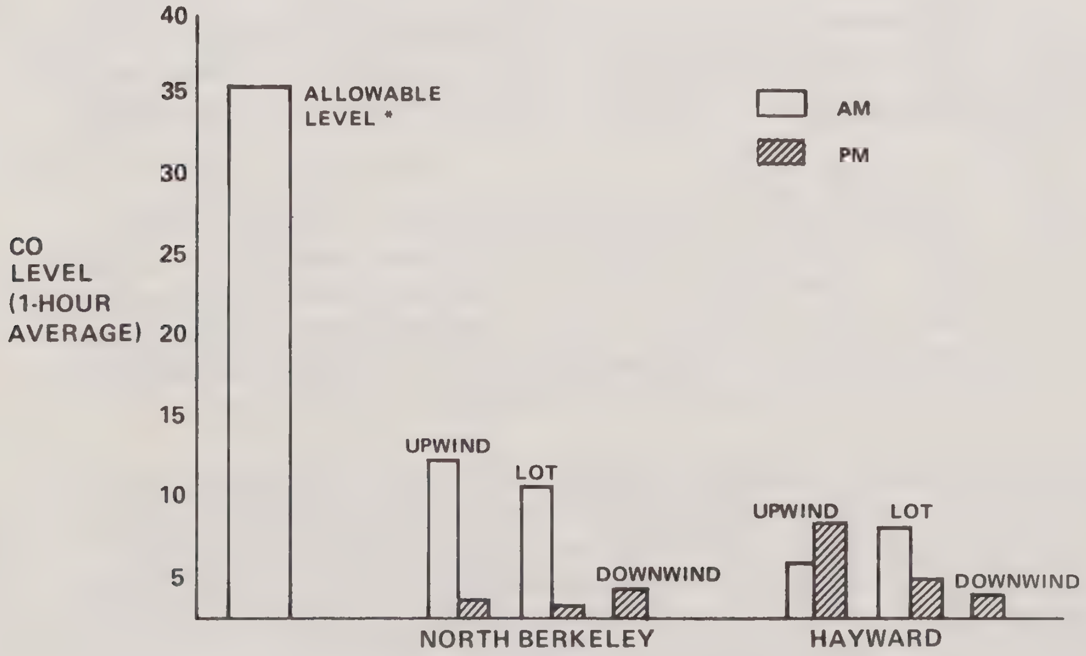
[1] ppm stands for parts per million.

Levels of CO monitored at the neighborhood downwind site adjacent to the Hayward BART parking facilities were found to be somewhat lower than CO levels measured at the control sites. Levels of CO measured at the neighborhood site next to the Berkeley BART parking facility were slightly greater than those at the corresponding Hayward site (a concentration of 4.5 ppm compared to 3.0 ppm). However, this appears to be due more to heavy traffic on a nearby arterial (Sacramento Street) than to the influence of BART parking lot activity (WP, p. 40).

From the limited measurements that were taken, it is evident that BART's effects on local air quality are minimal (Figure 12). In some instances (Hayward in the afternoon peak period) the downwind or neighborhood site had lower readings than those of the lot or upwind sites. The North Berkeley downwind site was slightly higher than the upwind or lot sites, but at levels that were not appreciable.

Figure 12
MAXIMUM 1-HOUR AVERAGE CO LEVELS IN AND AROUND BART STATIONS



* National Ambient Air Quality Standard—35 ppm for 1 hour.
NOTE: No downwind AM measurements were taken.

What are the major factors affecting the level of pollutants?

The most significant attributes which affect local air quality at a given site in the vicinity of the BART stations were identified as:

- Meteorological characteristics
- Traffic activity and behavior in the BART parking lot
- Proximity to traffic activity

Wind velocity and direction is an important impact determinant affecting local air quality in the vicinity of BART stations (WP, pp. 28-40). During periods of unusually stable atmospheric conditions, ambient concentrations of CO build up steadily over the station parking lot and throughout the adjacent neighborhood.

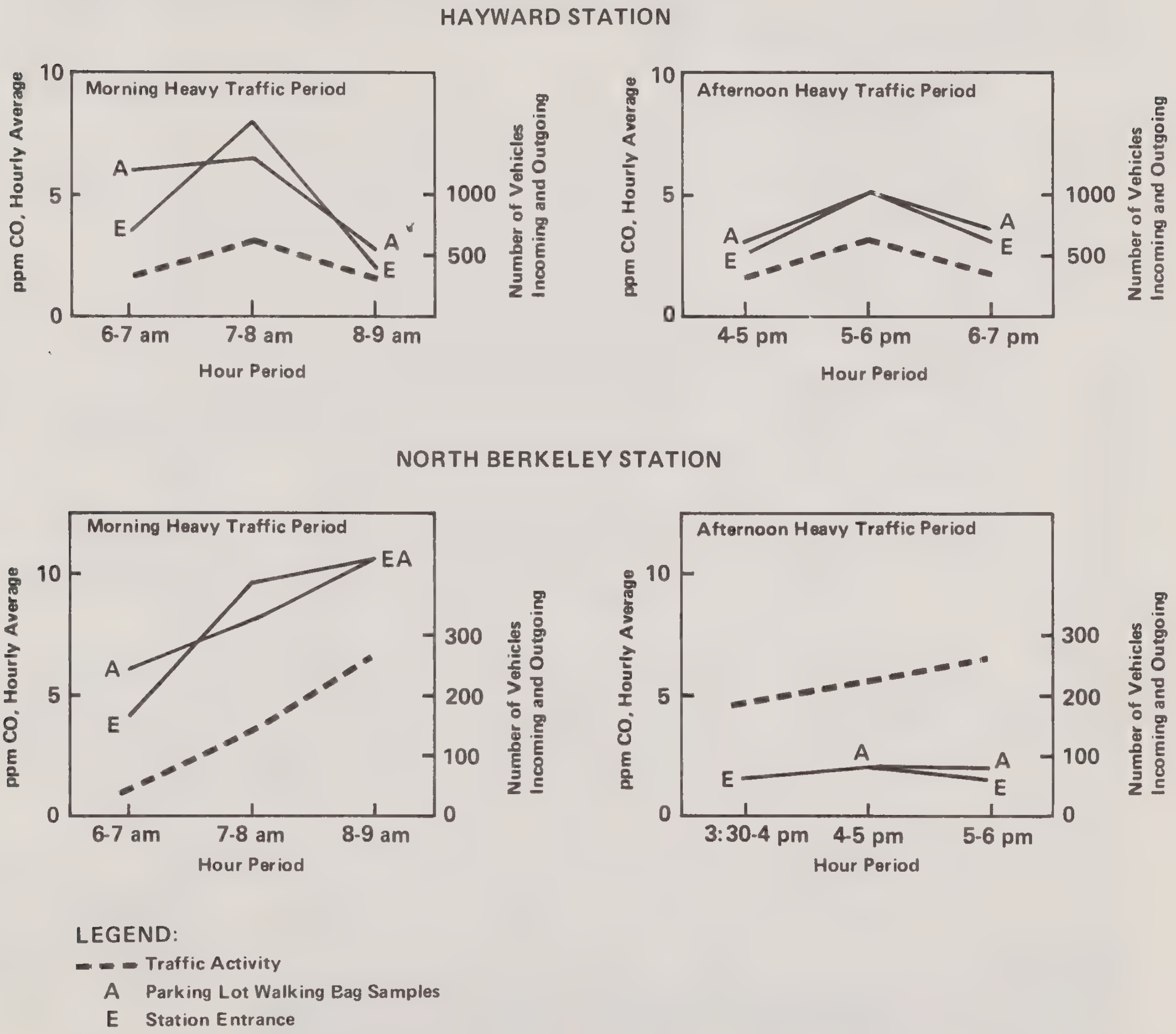
BART's greatest impact on local air quality occurs during the heavy traffic periods of the morning and afternoon. Because stable atmospheric conditions conducive to pollutant buildup were more frequent in the morning hours, the impact of BART-induced traffic emissions was generally greater there.

However, this phenomenon is not peculiar to areas at BART stations. CO levels at other study sites (control sites) upwind of BART-related traffic were also observed to increase steadily during periods of stable atmospheric conditions.

The atmospheric diffusion rates associated with typical Bay Area atmospheric conditions are apparently sufficient to prevent heavy ambient CO buildup in the vicinity of the BART stations. While ambient concentrations of CO at the stations may be expected to increase somewhat during the heavy traffic periods of the morning and afternoon, the peak levels which occur are generally short term and relatively low in magnitude.

The level of BART-related traffic activity at the BART stations was an important variable in ambient CO levels at the station (WP, pp. 42-48). For a given wind strength and ambient site, a certain level of traffic activity is needed to generate a given ambient level of CO. This relationship is shown in Figure 13, as peak levels in the parking lot occur coincident with peak levels of parking lot activity.

Figure 13
RELATIONSHIP OF TRAFFIC ACTIVITY AND AIR QUALITY



Air quality in the neighborhood surrounding the BART station is directly related to the level of BART-induced traffic activity on the streets providing accessibility for the BART stations (WP, pp. 48-50). The impact of BART-related street traffic on local air quality is most pronounced in the morning heavy traffic hours, when the proportion of all street traffic in the vicinity of the station bound for or departing from the BART station is greatest.

The nature of traffic behavior in the BART parking lot was also an important variable influencing the magnitude of CO emissions. Vehicular emissions of CO differ substantially between the distinct driving cycles associated with motor vehicle behavior at the BART facilities (WP, pp. 50-52), of which the main patterns are:

- Enter and park
- Enter and stop, start and exit
- Enter and stop/idle and exit

  Kiss and ride pattern
- Cold start and exit (afternoon exit)

Primary determinants of traffic behavior at the BART parking facilities are: parking lot occupancy, level of traffic activity and parking lot configuration. Traffic congestion, caused by combinations of these determinants, affects traffic behavior dramatically. Emissions of CO from the vehicles are proportional to the level of traffic congestion, which is measured by frequency of vehicle stops and the duration of travel through the parking lot.

Traffic congestion does not increase appreciably with increasing lot occupancy. The small amount of congestion observed is apparently attributable to the parking lot design, which features separate access ways to the multiple lot segments, spacious parking lanes, and a central station entrance.

Proximity to traffic activity was a consistent determinant of CO levels. The highest levels of CO (12.5 ppm) were found in the parking lot near the entrance to the BART station. Levels of CO observed at sites in the area surrounding the BART station are generally highest at the sites near a major traffic arterial.

Street level ambient concentrations of CO diminish rapidly with distance from the impact origin. Variations in CO concentrations in the vicinity of the BART stations are related to CO source activity in the immediate area of the sampling site. The highest CO levels were consistently found at the sites near the more heavily traveled streets.

MICROCLIMATE

The construction of BART has resulted in alterations to existing land use patterns and individual structures in order to locate the line (aerial and

berm configuration), station facilities, parking lots and other BART-related facilities. Neighborhoods have witnessed both the removal of entire blocks of houses and the emplacement of structures where none previously existed. These changes were examined to evaluate their possible modifying effect on local microclimate.

Methodology

For the purposes of this study, microclimate was defined as meteorological phenomena, such as wind and temperature, whose scale of analysis is in the order of magnitude ranging from a few square meters to a square kilometer. The evaluation of the impact of BART structures and open space on wind conditions was conducted by a trained meteorologist and is based on his professional judgement. Temperature impact evaluation was made from actual field measurements. The impact of BART on macro-scale meteorology (i.e., the entire Bay Area) was not examined, as the nature and extent of BART structures were judged to be negligible in possibly affecting regionwide termperature and wind conditions.

Issues and Findings

What is the effect of BART facilities on local microclimate?

The primary finding drawing from the sampling of BART conditions is that the effect of BART structures on local microclimate is minimal. The conditions under which some change was found where those from the channeling of wind around the base of elevated stations (such as El Cerrito del Norte) and beneath aerial sections of trackway (such as along Grove Street). In theory,

Plate 9
ELEVATED BART STATION—EL CERRITO DEL NORTE

these conditions can result in an approximately 20 to 30 percent increase in wind velocity experienced in the areas downwind and immediately adjacent to these situations. However, no wind velocity measurements were taken to verify these theoretical projections (WP, pp. 85-89).

Wind that has been disturbed by passage over obstacles, or wind that has been channelized by passage along city streets, tends to become reconstituted after re-entering an open area. These conditions occur at a number of BART station parking lots and in downtown areas where station plaza areas have been created.

In areas previously occupied by buildings and/or vegetation (i.e., trees) which have been cleared to create parking lots or plaza areas, an increase in wind velocity is likely to be experienced (WP, p. 89). These obstacles acted as a wind barrier, and, with their removal, the wind which has been disturbed by passage over other structures tends to reconstitute itself in the open area. Buildings or people facing the wind at the end of parking areas or plaza spaces could be subjected to wind velocities as much as 30 to 50 percent higher than they had previously experienced.

Plate 10
CLEARED AREA FOR A BART PARKING LOT— NORTH BERKELEY

Where large parking lots are divided into a number of smaller components (rather than a single lot), and where extensive landscaping was used, the downwind effect could be mitigated by preventing or lessening the reconstitution of wind flow.

<u>What other microclimatological effects could be detected as a result of BART facilities?</u>

BART <u>ventilation facilities</u> are of a negative pressure variety (intake vents). Consequently, there was no observable impact on ambient air temperatures or localized turbulence due to the presence of the vents.

Temperature measurements taken at a number of BART parking lots indicated that there were no significant differences between air temperature over asphalt parking areas as compared to uncovered ground.

Because of the relatively low profile of BART-related structures, the daytime shadows created by those structures have no measureable impact in changing temperatures. Visual impacts as a result of shadows are further discussed under the Visual Quality findings.[1]

[1] Chapter VIII, BART Impacts on the Visual Environments.

VI. BART IMPACTS ON THE NATURAL ENVIRONMENT[1]

INTRODUCTION

This general subject area is organized into three categories:

- Biota (Wildlife and Vegetation)
- Soils and Geology
- Drainage and Water Systems

In this chapter, findings are grouped accordingly.

It is a significant feature of BART that virtually the entire area traversed by its lines is urbanized and fully developed. Little "natural" or "semirural" land is found near the system. As shown in Figure 14, such areas include primarily the eastern slopes of the Berkeley Hills, San Francisco Bay, and the very southern end of the Fremont line. In addition, one (minor) unchannelized watercourse is crossed by a BART line. Consequently, the natural environment was not a major topic of study. However, since some impacts on the natural environment are often not very visible or apparent even when quite significant ecologically, this study included a general but comprehensive review of the BART system's possible impacts on the natural environment. This effort included on-site and aerial observation, review of relevant literature, study of available documentation of the region's natural characteristics, and consultation with a number of environmental specialists, local government representatives, and BART staff.

Data required for study of the temporary effects of BART construction on the natural environment were generally not available. Consequently, only a very general treatment of such effects was possible in this study, and emphasis is instead placed on present impacts of the BART structures and operations themselves.

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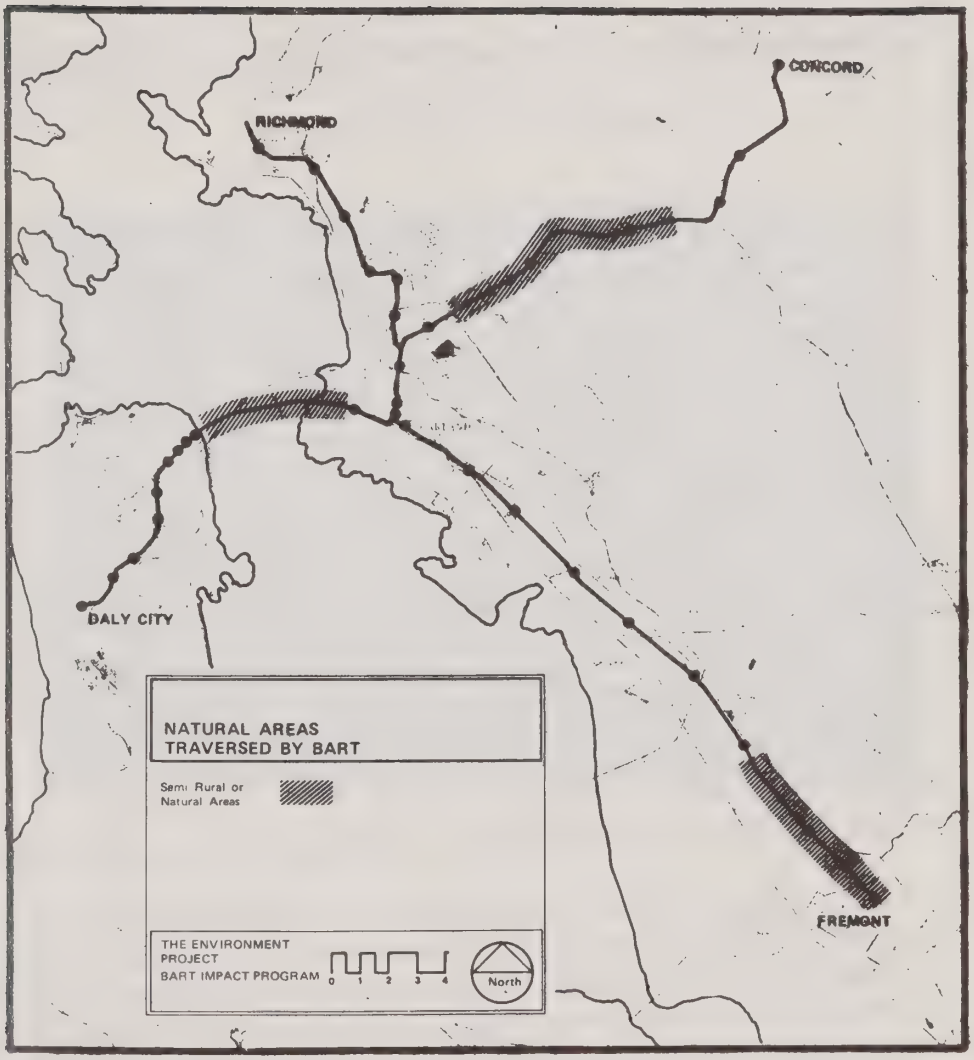
[1] De Leuw, Cather & Company (1976), Impacts of BART on the Natural Environment - Interim Service Findings, Berkeley: Metropolitan Transportation Commission. References in this chapter to a Technical Memorandum (TM) refer to this document.

Figure 14
NATURAL AREAS TRAVERSED BY BART



BIOTA

The term "biota" refers to the natural environment's living portion, including both vegetation (flora) and wildlife (fauna). These two aspects tend to be highly interdependent, with species of each acting as members of the same complex ecosystems. Consequently, the study of BART's biotic impacts was not organized by these two components. Instead, a five-subject organization was used to assure a more comprehensive coverage.[1]

[1] Approach adopted from Alan M. Voorhees & Associates, Inc. (1975), Interim Guidance Manual for Environmental Assessment for Use by HUD Field Office Personnel, Washington, D.C.: Office of Policy Development and Research, U. S. Department of Housing and Urban Development.

Methodology

The five subject areas included in the biota study were as follows:

- Vegetative communities
- Rare or endangered wildlife species
- Diversity of ecological communities
- Biotic productivity (plant and animal increase)
- Nutrient cycling (flow of minerals)

Potential impacts within each of these subject areas were pursued through an initial screening of issues using MTC's existing Bay Area ecological inventory maps of environmental features. This was followed by direct observation of points of possible impact and interviews with specialists in specific fields such as marine biology. No detailed field data collection was required.

Issues and Findings

How has BART affected the vegetative communities along its route?

BART affected local vegetative communities both by removal during its construction and later replacement with new landscaping. No significant impacts on vegetative communities were caused by the removal of vegetation for construction. Although quantitative estimates of the extent of this removal were not available, much was removed from the right-of-way in some locations. This included many large trees. However, the removal of trees along BART had no significant ecological impact due to the small and narrow areas affected relative to the size of their similar surroundings. The loss of mature trees in urbanized areas is primarily a visual aesthetic impact rather than an ecological one. Such aesthetic impacts were studied further in the Project's assessment of effects on visual quality.[1]

Approximately $6 million, or 0.4 percent of BART's total construction cost, was spent on landscaping. This resulted in a varying but typically low-to-moderate level of landscaping, consisting primarily of small shrubs, street

[1] See Chapter VIII, BART Impacts on the Visual Environment.

trees, and ground cover planting. No appreciable quantity of large trees was included. Most landscaping was placed at suburban stations and parking lots, as well as in some areas beneath aerial trackways. This landscaping has had no apparent effects on surrounding existing vegetation (TM, pp. 27-31).

Plate 11
LANDSCAPING IN BART STATION PARKING LOT– PLEASANT HILL

The BART landscaping program itself is of interest. Landscaping was originally planned to include only ground cover on slopes for erosion control, in keeping with the general principle of minimizing the BART system's operation and maintenance costs. However, public meetings during the planning process revealed substantial community concern with landscaping, and emphasis and funds for this purpose were subsequently increased.

As the program developed, Lawrence Halprin & Associates were retained as consulting landscape architects. This led to creation of a landscape design criteria manual.[1] A dispute arose over the nature of Halprin's role, and he resigned before construction began. The design work continued without a landscape consultant. Ultimately, the landscaping design was carried out by eight different firms and installed under 33 separate construction contracts. After installation, maintenance responsibility was apportioned among the local jurisdictions as well as BART. These arrangements varied from place to place.

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[1] Lawrence Halprin & Associates (1964), Landscape Design Criteria, Rapid Transit: First Report, San Francisco: Bay Area Rapid Transit District.

Much of the additional financial assistance required for the enlarged landscaping program was obtained from the U. S. Department of Housing and Urban Development. They funded 90 percent of the linear parkway demonstration[1] in Albany and El Cerrito, as well as 50 percent of all other landscape design costs (TM, pp. 31-33).

Did BART disturb any rare or endangered species?

At least five rare or endangered species of wildlife are found in the San Francisco Bay area, as well as a number of ecologically important habitats.[2] However, study revealed that the BART route avoids known sensitive environments containing these rare and endangered plant and animal species.

BART traverses the habitats of a great variety of other plant and animal species. These habitats surrounding the BART system consist primarily of vegetation and wildlife common to urban residential and street environments. The plant material typically is not native to the region, and the wildlife communities consist primarily of small birds, mammals, and rodents not sensitive to an urbanized environment. Where BART traverses a more natural landscape, the vegetation is more indigenous to California, and wildlife communities include some larger mammals and birds (TM, pp. 20-27).

Has BART affected ecological aspects such as diversity, reproduction, and the food chain?

There is great diversity within the plant and animal communities affected by BART. This implies that the changes introduced by BART are likely to have only limited effects on the total communities surrounding the BART right-of-way. There was no indication of any significant impact on diversity. Similarly, the BART system did not significantly reduce regional biotic productivity (reproduction) or nutrient cycling (food chain). These important ecological processes were reduced only on the BART right-of-way; the significance of this impact is negligible, considering the limited area of the right-of-way in contrast to its surroundings.

An issue of particular interest relative to productivity was whether heat transmitted from the Transbay Tube into the cold bottom waters of San Francisco Bay would upset established marine ecological systems. Experts

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1 See Chapter VIII for more on the linear parks.

2 Metropolitan Transportation Commission (1974), Draft Environmental Impact Report for the Metropolitan Transportation Plan, Berkeley: Metropolitan Transportation Commission.

consulted judged that such effects on aquatic systems were negligible, only slightly increasing productivity, if at all. Similarly, since the tube is actually in a now-silted-over trench beneath the bay floor, it poses no barrier to migrating bottom-dwelling organisms such as crabs (TM, p. 34).

SOILS AND GEOLOGY

This category encompasses BART's impacts on the non-living portions of the natural environment. Water systems are excluded and treated as a separate category, which follows this section.

Methodology

The fundamental concern in the soils and geology category is stability. Impacts occur where construction causes soil and geologic conditions to become less stable and therefore more likely to shift, for example, by landslides or erosion. In addition, the use or consumption of unique or valuable geological resources is of concern here. Consequently, this study included review of the following subtopics:

- Slope stability
- Valuable geological resources
- Unique geological features
- Impermeable strata
- Weathering

In addition to BART's potential impacts on soils and geology, it is also possible that geological processes such as consolidation or earthquakes could have substantial effects on BART itself. This study, therefore, also encompassed the study of three additional subtopics:

- Consolidation
- Seismic activity
- Subsidence

Potential impact topics were first screened through interviews with officials of BART and communities along the lines. Maps of Bay Area geologic structures were also reviewed to identify locales of steep slopes, unstable

soils and other significant natural features. Further familiarity was gained through an aerial reconnaissance of the BART line, using photography as well as direct observation to identify points of landslide, erosion, sedimentation and major landform alteration. Additional on-site observations and interviews focused on areas in which potential impacts were identified by the screening process. No further field data collection was required.

Issues and Findings

Did BART construction create new dangers of landslide or erosion?

Major hillside grading for BART construction was required in only one general area, that of the eight-mile Orinda-Walnut Creek section of the Concord line. In this area, the topography is steep and rugged in contrast with the generally flat terrain throughout the remainder of the BART right-of-way. Geologic conditions in this hilly area are unusually unstable; the "Orinda formation," a highly expansive, uplifting, easily weather-weakened clay structure, is prevalent and highly susceptible to landslides.

Plate 12
SLOPE CUTS AT ORINDA STATION

As a part of BART construction from Orinda to Walnut Creek, a major highway (State Route 24) through the hills was widened to allow placement of BART tracks in its median. This required extensive new slope cuts in the Orinda formation, particularly at the Orinda station, where over four million cubic yards of soil were removed. Continuing although generally minor landslides and erosion have resulted.

In the Hayward-Fremont area, heavy rains in the first two years following construction of BART trackway embankments caused severe erosion and gullying of the four and one-half miles of embankment there. This necessitated extra effort by BART in sediment removal and slope repair. However, the problem has since been controlled with ground-cover planting. No other landslide or erosion problems were found (TM, p. 54).

Were any unique or valuable geologic resources lost as a result of BART construction?

The BART system is not located in areas of special geologic interest. Although extensive hillside excavations were made between Orinda and Walnut Creek, the hills and valleys altered are not unique either within or beyond the Bay Area. These excavations generally only widened existing freeway cuts, rather than making basic topographical changes. Such alterations were therefore judged not to be significant disruptions to special geologic features.

Most of BART's construction was near the ground surface, primarily above the water table. In other areas where deeper construction was employed, notably the downtown subways, there was no indication of effects on vertical or lateral ground water flow. Although data on depths of impermeable strata were not available, their presence is doubtful since most of BART's subway mileage was built in areas of deep silt and bay mud (TM, pp. 51-52).

Is BART subject to present or potential dangers of differential settlement or earthquake?

There is evidence that the unstable soil conditions in the Orinda-Walnut Creek area are causing slight deformations in the new highway pavement and BART track alignment. This deformation is also found in the Orinda station parking lot. It is caused by seepage of ground water and will be a continuing maintenance problem.

Apart from this situation, BART facilities have suffered no significant impacts of differential settlement or surface deformation (TM, pp. 55-56). This was due, at least in part, to the emphasis given to this potential problem during BART's design. Special design features included the following:

- Pilings under trackway columns, to minimize settlement.

- Simple span beam design for elevated trackways, to simplify any track realignment required later.

- Granular base material under the Transbay Tube, spreading the weight evenly over the soft bay mud.

There is a widely acknowledged potential for seismic activity in the Bay Area. The BART tracks cross one major fault zone, the Hayward fault, at the western end of the Berkeley Hills tunnel. Consequently, BART's design included a number of measures to minimize the effects of shear zone movement on its facilities and operations (TM, pp. 56-58):

- Berkeley Hills tunnel: easily replaceable short concrete tunnel lining sections, larger diameters, maximum distance between the two one-way tunnels, crossover tracks connecting the two tunnels, and fault deflection meters for early warning.

- Elevated trackways: simple span construction, with pin connections between beams and columns to prevent displacement.

- Transbay Tube: granular base to mitigate liquefaction effects.

DRAINAGE AND WATER SYSTEMS

The emphasis of this assessment has been on the effects of BART facilities on local natural water systems, particularly near BART's parking lots. Since most watercourses crossed by BART were already channelized and lined, few impacts on natural water systems were to be expected. However, there are a variety of potential impacts which do not require the immediate presence of natural streams. Potential types of impact studied included the following:

- Surface drainage
- Storm water flooding
- Water quality
- Sedimentation
- Aquifer yield
- Ground water recharge

In addition, potential impacts on BART itself from the leakage or failure of water impoundments were investigated.

Methodology

In this study, primary reliance was placed on interviews with public works officials of communities along BART. In addition, interviews were held with officials of BART and its engineering design consultant who had been involved in this aspect of the original BART design. Aerial photographs were also reviewed, and on-site inspections were made in locations of possible impact. Finally, MTC ecological inventory maps were used to identify ground water recharge areas.

Issues and Findings

Has rainfall runoff due to BART facilities been beyond local storm drainage capacity?

Each of BART's parking lots has from two to eight acres in paved or impermeable surface area, thereby increasing local rainfall runoff. In all cases, BART construction included provision of adequate storm sewer capacity for this additional flow. This effort went so far as to increase, beyond BART's requirements, the size and capacity of nearby municipal storm sewers in two cities, to provide capacity for expected BART-induced growth.

No major flooding has occurred due to BART. Some minor flooding has occurred at points in Richmond, El Cerrito, and Orinda, generally due to temporary clogging of drainage culverts and ditches, as well as inaccuracies in landscape grading. Most of this flooding has been confined to BART property, and no significant property damage or personal danger has been noted (TM, pp. 71, 74).

Have contaminants in BART runoff waters adversely affected public water supplies or natural habitats?

Inspection of aerial photographs, interviews with local officials, and site inspection revealed only one indication of significant <u>sedimentation</u> effects either from BART construction or operations. This was in the case of the trackway embankments between Hayward and Fremont, which were heavily eroded by rains before ground-cover planting could become established. The resulting sediment was deposited in local drainage channels and, according to a Hayward city spokesman, contributed to local storm sewer maintenance costs. This condition was ultimately corrected by ground-cover planting.

Virtually all runoff from BART facilities is channeled into lined storm drains with ultimate discharge into San Francisco Bay. At the points of discharge, BART's contributions to total volume are insignificant. In one instance, a natural pond at the Fremont station, aquatic life was present and conceivably could have been affected by contaminants in parking lot runoff. However, there was no indication of such effects.

BART is not located in the region's primary ground water recharge zones, and in only one area traversed (Orinda-Lafayette) does surface drainage contribute to local water supply. Even in that area, the eight-acre total land surface occupied by BART's parking lots is an insignificant loss in permeable surface. Aquifer yields were likewise unaffected since the scale and depth of BART-related earthwork were not sufficient to cause such impacts. Major grading occurred only in the Orinda-Walnut Creek area, and no significant aquifers were exposed (TM, pp. 71-74).

Is any of the BART system located so as to be endangered by dam failures?

Four artificial impoundments are located upstream and near portions of BART's Fremont line. According to the Alameda County Office of Emergency Services, at least three of these may be large and close enough to damage the BART facilities in the event of a dam failure such as might occur in a major earthquake (TM, pp. 75-76). The exact earthquake magnitude required to cause such a catastrophe is not known, but is probably so large as to be of extremely low probability. Further study of this potential danger is included in a current State of California program on possible effects of earthquake-related dam failures.[1]

[1] State of California, Office of Emergency Services, as authorized under Senate Bill 896.

VII. BART IMPACTS ON THE SOCIAL ENVIRONMENT[1]

INTRODUCTION

The scope of the Environment Project's "social environment" is a narrow one, based on the study's concern with the effects of BART as a physical entity. In this context, the impacts of interest are primarily those which influence the interactions of people in the vicinity of BART. The effects of BART's facilities on privacy are also included. Four impact categories were used to organize this assessment:

- Barriers
- Safety (against accidental bodily harm)
- Security (against threats to persons or property)
- Visual Exposure

About 85 percent of BART's alignment parallels prior transportation corridors, and local adaptations to these kinds of impact had therefore already been made to some extent. However, BART facilities and operations still constituted a major change in the physical arrangement, so additional impacts could be expected in these four categories.

The effort included the gathering of complementary types of data, widespread interviews with BART and community officials, consultations with knowledgeable professionals, and direct observation in specific locations. Wherever "hidden" impacts seemed plausible (e.g., unobservable responses to intrusion of privacy), further exploration was left for Phase II study.

BARRIERS

The overall objective of the barrier analysis was to assess, on a systemwide basis, the effects of BART facilities on the ease or hindrance of pedestrian and vehicular movement in areas adjacent to BART lines and stations. This effect of BART as a potential source of barriers extends beyond the actions of BART itself to public improvements taken by adjoining communities in direct response to BART's construction.

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[1] Gruen Associates, De Leuw, Cather & Company (1976), Impacts of BART on the Social Environment - Interim Service Findings, Berkeley: Metropolitan Transportation Commission.
References in this chapter to a Technical Memorandum (TM) refer to this document.

The movement patterns of concern are those which cross or run immediately parallel to BART's alignment, and barriers were defined as any physical impediment to these movements by pedestrians or vehicles. To the extent possible, the study was directed at asssessing effects of the difference in movement between BART and as it would have been had BART not been built (TM pp. 25-28).

Methodology

Comparison of 1965 aerial photographs (prior to BART construction) with those of 1972 (after the system was built) in the system corridor, and discussions with BART representatives, provided a systemwide catalog of changes in movement. Field observations and discussions with local traffic officials and BART representatives provided the qualitative information needed to arrive at conclusions about the movement changes. Topics considered in the barrier study are:

- Alignment
- Configuration
- Easements to movement
- Non-movement effects

A fifth possible topic, that of BART construction's effects on movement, was not a part of this project.[1]

[1] During BART construction the downtown areas of San Francisco, Oakland and Berkeley were the scenes of extensive activity to put BART in a subway beneath main streets. These construction activities resulted in numerous detours and obstructions to motorists and pedestrians which ranged in duration from about two years in Berkeley to more than seven years in San Francisco. Though not directly involved in effects on movement, utility networks beneath downtown areas and the Bay were considerably affected by BART construction. There was substantial reorganization, rerouting, and repair of subsurface utility lines and transbay communication and electrical cables. It also provided an opportunity for comprehensive mapping of these lines, many of whose exact locations were previously unknown.

Issues and Findings

What is the relationship between BART alignment, configuration, and previous transportation facilities acting as barriers?

About 85 percent of BART's alignment parallels prior transportation corridors (Table 14 and Figure 15). However, for at-grade and aerial sections only, over 95 percent of the alignment parallels other transportation facilities. Consequently, even before BART, local adaptations to barrier effects had taken place.

The type of adjacent transportation had an important effect on the intensity of cross traffic along BART's alignment. About one-third of BART's total alignment, where it is adjacent to arterials and infrequently used railroads, has intense cross movements (as measured by number of crossings per mile), while approximately one-half, where it is adjacent to freeways and heavily used railroads, has infrequent cross movement (Table 13).

Table 13
ADJACENT TRANSPORTATION FACILITIES AND CROSSING FREQUENCY (PRIOR TO BART)

		ADJACENT TRANSPORTATION RIGHTS-OF-WAY					
		Freeway	Heavily Used Railroad	Lightly Used Railroad	Arterial	No Prior Adjacent Transportation	Total
BART	*Miles*	14.1	21.6*	5.2	18.3	11.8	71.0
	Crossings	43	47	32	154	15	291
	Crossings per mile	3.0	2.2	6.2	8.4	1.3	4.1
	Miles	35.7		23.5		11.8	71.0
	% of 71 miles	50%		33%		17%	100%

* This includes 4.1 miles between Concord and Pleasant Hill stations which were originally heavily used but were abandoned in 1962.

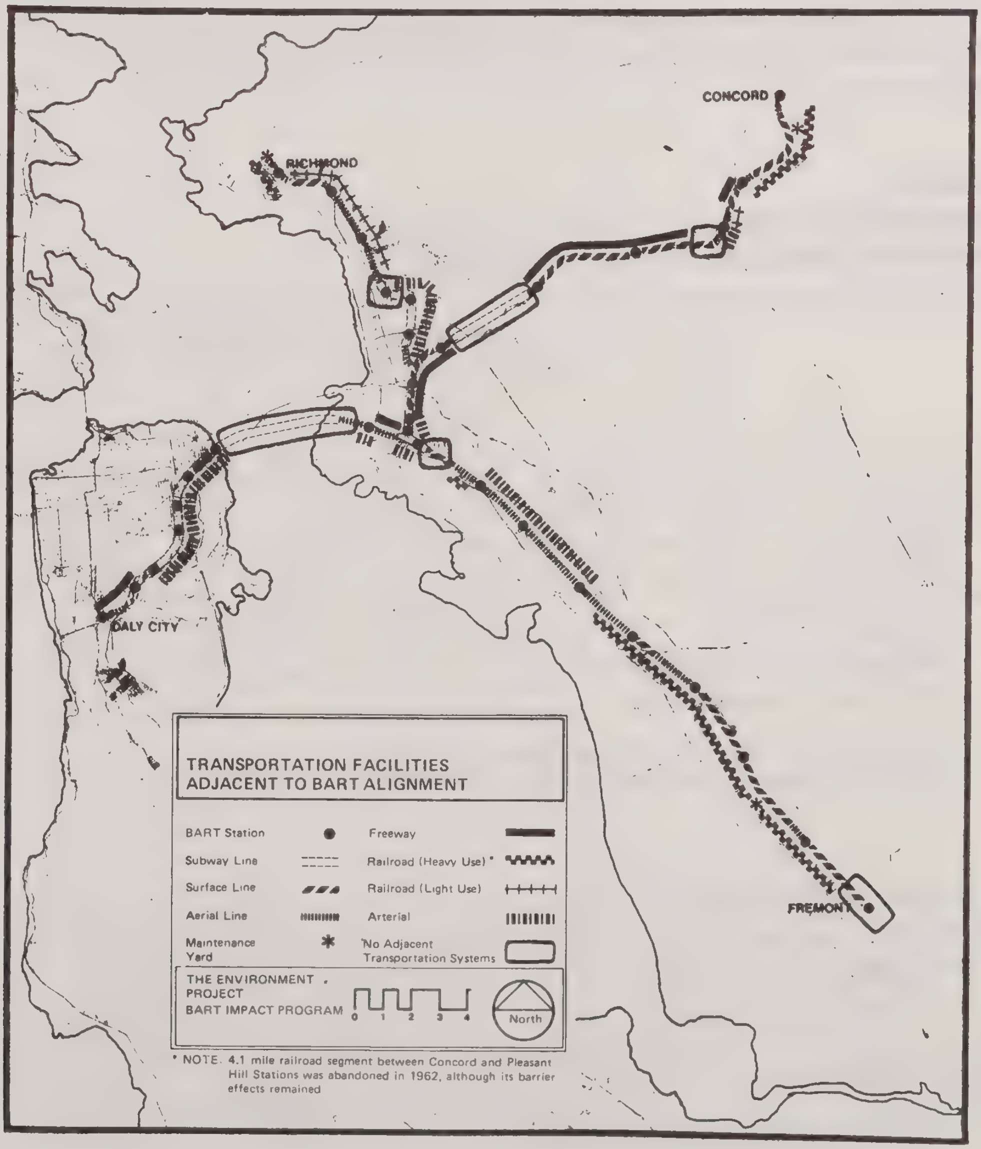
Of major importance is the fact that BART responded by using three types of configurations in a way which created minimum barrier impact. BART subway and aerial configuration was used primarily in areas with parallel arterial and railroad alignments and was associated with heavy cross traffic. On the other hand, BART surface configuration was used predominantly in areas where previous strong barriers (freeways and heavily used railroads) exist.

Table 14
ADJACENT TRANSPORTATION AND THE BART CONFIGURATION

	Freeway	Heavily Used Railroad	Lightly Used Railroad	Arterial	No Prior Adjacent Transportation	Total
Subway miles	1.3	—	0.2	9.4	9.4	20.3
Surface miles	9.9	14.8*	1.0	—	1.4	27.1
Aerial miles	2.9	6.8	4.0	8.9	1.0	23.6
TOTAL	14.1	21.6	5.2	18.3	11.8	71.0

* Includes 4.1 miles abandoned in 1962.

Figure 15
TRANSPORTATION FACILITIES ADJACENT TO BART ALIGNMENT



Because of this, only 12 of the almost 300 streets crossing the BART alignment were blocked and these were generally requested or unopposed by local communities. None involved major traffic streets. In addition, all major pedestrian paths were replaced with grade separations.

What improvements in access and ease of movement have been made by BART?

Numerous grade separations and parallel traffic improvements resulted from BART's construction (Table 15). In some locations, new roadways have provided access where this was previously not possible (TM, Appendix A-2).

Table 15
ADJACENT TRANSPORTATION AND CIRCULATION IMPROVEMENTS RESULTING FROM BART

	Freeway	Heavily Used Railroad	Lightly Used Railroad	Arterial	No Prior Adjacent Transportation	Total
Cross traffic improvement	11	21	0	5	3	40
Miles of parallel improvement	6.7	6.0	3.6	7.6	–	23.9

Plate 13
VEHICULAR GRADE SEPARATION–SAN LEANDRO AREA

Parallel railroads and major traffic streets, along with BART, have been grade-separated from cross traffic.

Plate 14
PEDESTRIAN BRIDGE—HAYWARD

Pedestrian bridges have been constructed in residential areas and near schools.

Plate 15
PARALLEL FREEWAY IMPROVEMENT—LAFAYETTE

A 7-mile major freeway segment was widened and improved in conjuction with BART construction. Several arterials were widened and improved with medians to accommodate BART aerial structures. New or improved frontage roads were provided in locations adjacent to heavily used railroads.

In addition, three major urban boulevards were refurbished and traffic improvements made: Market Street in San Francisco, Shattuck Avenue in Berkeley, and Broadway in Oakland. Along Market Street, station mezzanines provide weather-protected and traffic-free crossing.

What effects, if any, has the existence of the Transbay Tube had on maritime activity on the Bay?

According to the Coast Guard Vessel Traffic System (the maritime traffic authority on San Francisco Bay), the BART Transbay Tube has had no effect on maritime activity on the Bay, and even during construction, when barges and rigs were present on the Bay, ships were easily rerouted around them.

Were there any other notable barrier effects resulting from BART?

In Concord, the BART line is on an earth embankment which physically and visually separates a residential area from an industrial area. After seeing the positive effect BART had in separating these two incompatible land uses, the community decided to drop plans to request BART to provide additional overpasses.

In Union City, a similar effect was achieved. An earth embankment and the Union City station have partially separated heavy industrial facilities from a new residential area.

SAFETY

The analysis of BART's impact on safety focused on changes in the occurrence of traffic and non-traffic accidents as well as accident potential attributable to BART in areas adjacent to BART stations and along its lines. These areas included BART station parking lots, but excluded areas inside stations and on BART trains. Accident potential was defined as the presence, to varying degrees, of factors which contribute to the cause of accidents, i.e., the likelihood that accidents may occur. The factors were identified by interviews with traffic engineers and study of standard traffic engineering references.

Methodology

This investigation was built upon several different types of data, including accident statistics and reports from BART and local jurisdictions, interviews with BART and community police, public officials and patrolmen throughout the system, traffic volume data, census, and direct observation. The study approach focused on a comprehensive assessment including preliminary interviews on a broad scale and subsequent selection of representative sites for more detailed interviews and collection of other data. Finally, a synthesis of these studies involved derivation of systemwide estimates of impact and its major determinants. Where available data allowed and when applicable in specific situations, statistical comparisons were made to determine the significance of findings (TM, p. 39). Some

methodological discussion is included under Issues and Findings where applicable to specific topics.

The issues and findings are presented here for traffic safety (by general location and type) and specific non-traffic safety impacts.

Issues and Findings

Have traffic accidents or accident potential attributed to BART changed significantly?

(a) Along BART lines

(b) In downtown stations[1]

(c) In all other stations specifically with relation to:

- parked cars on nearby streets
- moving vehicles on nearby streets
- pedestrian and vehicle movement in BART parking lot

(a) Traffic Safety: Lines

One might expect that necessary street closures and rerouting from BART operations and facilities could have caused many negative changes or, conversely, the placement of BART lines might have provided many opportunities to improve previously unsafe traffic conditions. However, neither condition seems to have occurred.

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[1] Downtown stations are defined here to include the eight in the main business districts, as follows:

San Francisco CBD (Civic Center, Powell and Montgomery;
Embarcadero omitted since not yet open)
San Francisco Mission District (16th Street, 24th Street)
Oakland CBD (12th Street, 19th Street)
Berkeley CBD (Berkeley)

These stations are distinguished from all others by their subway configuration, relatively dense commercial surroundings and absence of BART parking lots.

The few significant BART-related improvements[1] in line area safety were found to be:

- Downtown street improvements in San Francisco, Oakland and Berkeley which were largely BART-induced[2] include widening of streets and installation of better signalization and outdoor lighting equipment. These have resulted in easing of pedestrian and vehicle flow and parking improvements.

- Vehicular grade separations where roads previously intersected railroads have been constructed in the Richmond, Concord and Hayward areas, resulting in a decrease in actual conflict between systems.

- BART's construction of a pedestrian bridge over its tracks and an arterial street at the eastern portal of the Transbay Tube where pedestrians crossed in heavy traffic, resulting in a decrease in actual conflict between vehicles and pedestrians.

(b) Traffic Safety: Downtown Stations

Within the areas adjacent to station entrances and exits, actual accidents and accident potential have not changed or been attributed to BART-induced traffic. However, pedestrian travel patterns, particularly those of BART commuters from the East Bay to downtown San Francisco, were somewhat changed due to BART's station locations relative to bus terminals and auto parking lots. BART station mezzanines, street improvements and generally minor BART-related changes to bus traffic movement around downtown stations appear to have helped maintain the prior level of safety, despite increased concentrations of

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[1] BART construction, particularly cut-and-cover construction for portions of subway lines in urban areas, was considered by those interviewed in the pre-BART survey (Pre-BART Data Analysis, Environmental Project, draft Working Paper) to have reduced safety. Construction effects most often cited included creation of "dangerous areas" near BART. However, no further details were provided, and no statistics on BART construction accidents were found. Observations of current BART-related construction areas in San Francisco revealed that (a) often traffic regulations are unclear, if present at all, and (b) the allowed directions of traffic flow and regulations change often (TM, p. 43).

[2] Although BART provided the original impetus, actual sponsors of those improvements were local merchant associations, the municipalities involved, and the U.S. Department of Housing and Urban Development.

pedestrian movement. (Downtown BART stations exit anywhere from 2,000 to 14,000 patrons during a.m. peak periods; TM, pp. 44-45).

There is a minor exception at the Berkeley center city station. Pedestrians are required to cross a high volume street to gain access to bus service (University of California Humphrey Go-BART Shuttle Bus), resulting in increased violation of pedestrian traffic regulations and an increase in accident potential.

(c) Traffic Safety: All Other Stations

Parked Autos on Streets Near BART

In general there is little on-street parking by BART patrons. Two of the 25 stations in this category, Glen Park and Balboa Park, have no parking facilities due to San Francisco city policy. Both of these have significant on-street parking volumes. Of the 23 BART stations with parking lots, only two have substantial overflow--Daly City and Fremont (Table 16). Seven other station parking lots are at capacity and have overflow on-street parking.

Table 16
BART STATIONS WITH OVERFLOW PARKING

Station	Parking Lot Capacity	Overflow
Daly City	820	1,000
Fremont	700	550
Glen Park	0	350
Union City	477	350
Balboa Park	0	300
Walnut Creek	1,114	150
Lafayette	650	150
Concord	1,059	100
Pleasant Hill	1,337	100

As of January 1975.

Significant BART-related increases in accidents involving parked cars were found only near the Daly City station. There volumes of parked autos and increased traffic due to BART were very high on several two-lane residential streets. This station is the terminus of a line originally planned to extend much farther into San Mateo County, which subsequently voted not to join the BART district. However, many San Mateo commuters to downtown San Francisco drive to Daly City and thereby have created major parking problems.

A comparison was made between stations considered by local officials and traffic engineers to have appreciable future accident potential and those that did not (TM, pp. 48-52). The differences in conditions for stations with accident potential are:

- Adjacent two-lane residential streets
- Presently no or few available parking lot spaces
- A propensity for future local population growth or development
- No known plans for parking lot expansion or increased feeder bus service
- Locations on the Richmond line which will soon have direct transbay service

All or most of these conditions are present in ten stations:

Ashby	Concord
North Berkeley	Balboa Park
El Cerrito Plaza	Fremont
El Cerrito del Norte	Bayfair
Richmond	Pleasant Hill

Moving Vehicles on Streets Near BART

Significant increases in moving-vehicle conflicts[1] have occurred and been attributed to BART in some medium- or low-density station areas. These areas are those where traffic volumes related to BART have increased near principal station exits or entrances and where traffic controls either are not present or fail to operate effectively under the increased traffic volumes (TM, pp. 52-66). Such accident increases have occurred at the following station areas: Daly City, El Cerrito del Norte, San Leandro, Hayward, Union City and Fremont. Table 17 indicates the major causes of increased accidents around these stations.

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[1] Conflicts can be defined as movement patterns which could result in accidents.

Table 17
INCREASED MOVING-VEHICLE ACCIDENTS AROUND BART STATIONS

Station	Cause of Accident
Daly City	- High volume of auto and pedestrian traffic. - Pedestrian-auto conflict at station entrance. - Lane changes and complex intersections.
El Cerrito del Norte	- Changed patterns of vehicular movement. - Inadequate signalization.
San Leandro *Hayward* *Union City* *Fremont*	- High volume of bus, auto and pedestrian traffic. - Inadequate signalization. - Pedestrian-auto conflict at station entrance/exit.

From a comparison of these actual accident-producing conditions with the occurrence of such conditions systemwide, it appears that moving-vehicle accidents on streets near BART are likely to occur or increase in from 11 to 13 of the 25 station areas. These include the 10 stations already cited for their likely future parked-car accidents, plus Daly City, Walnut Creek and Union City. Significantly increased numbers of BART patron autos, particularly during peak periods, on streets designed for lower traffic volumes, are expected to contribute to accident increases. These volume increases are expected to result from future population growth or development in general as well as from commencement of direct transbay service on the Richmond line.

Parking Lot Accidents

BART's parking lots range from about 200 to over 1,400 spaces with a wide range of occupancy rates. Since BART, at the time of this study, did not run on weekends or at night, virtually all traffic into and out of its parking lots occurred during the morning and evening commute hours. In addition to auto parking, all lots have bus stops near the station entrances as well as internal facilities for auto passenger dropoff and pickup.

The number of reported parking lot accidents was generally insignificant during the first four months of transbay service (period for which data was analyzed). There are, however, certain conditions in lots which create accident potential. These conditions are the mixing of high pedestrian, auto and bus volumes near station entrances, and signing problems.

Several signing problems which are gradually being corrected were found to occur systemwide:

- Use of non-regulation signs which are generally smaller than standard and not easily recognized by drivers
- No directions to special parking spaces such as handicapped or midday parking spaces
- Inconsistent sign placement
- Station entrances and parking lot access not clearly marked
- Absence of marked no parking zones in lots to regulate auto parking (now largely corrected)
- Infrequent enforcement of parking lot regulations

Specific locations where there is a high mixing of pedestrian and vehicular movement in parking lots include:

- Bus versus other mode conflict (Walnut Creek, San Leandro)
- Pedestrian versus auto conflict (Fruitvale, Pleasant Hill, Daly City)
- Double parking of buses creating movement hazard (Bayfair and Fremont)

Has BART had any significant effects on non-traffic safety in line or station areas?

The greatest potential danger of non-traffic safety due to BART is trespassing because of the exposed 1,000-volt third rail. In 1973, 16 locations were identified by a BART-commissioned independent survey[1] as allowing easy unauthorized access to BART facilities and trackway. Most of the report recommendations have not been implemented except for the suggestion to build a previously planned pedestrian overpass to eliminate trackway trespassing in Richmond.

[1] Arthur Young & Company (1973), Final Project Report and Analysis of Police Services Division, San Francisco: Arthur Young & Company.

Despite the potential danger, BART police spokesmen stated that trespassing has not been a significant problem. The only traces of trespassing that have been found repeatedly have been cut fences in the Hayward and Richmond areas, apparently by juveniles seeking "short cuts" across the BART right-of-way. The Richmond problem was eliminated by the already-mentioned overpass.

Since the start of BART operations there have been only three accidents involving the public on trackways, two of which were apparent suicides. All occurred at station platforms rather than along the right-of-way. During 1974 transbay service, only five trackway trespassing incidents were recorded, four of which were at stations. There were no resultant injuries.

SECURITY

The investigation of BART's impacts on security focused on changes in crime and crime-related activities attributable to BART. Neighborhoods and other areas adjacent to BART stations, BART parking lots, and along the BART lines were included in this study. Areas inside BART stations and on trains will be studied in a separate task in Phase II. BART impacts were defined as appreciable[1] differences in crime or crime-related activity between what has occurred with BART and what would have occurred in the same locations and during the same period without BART (TM, p. 82).

Issues and their respective findings are presented according to three major locations types: areas along BART lines, downtown station areas as defined earlier in this chapter, and all other station areas. Together, these provide a comprehensive coverage of the BART system's major relevant facilities.

Methodology

The study approach utilized a variety of data sources and types. Initial rounds of interviews with city police and others were conducted throughout the BART system, followed by more detailed interviews with selected officials. Interviews with BART and local police officials allowed information to be gathered concerning the overall crime situation as well as

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[1] When more than one independent, informed source yielded credible evidence that a change or difference was regarded as meaningful in the local context, it was regarded as appreciable.

police policy. Interviews with station agents and patrolmen provided valuable input about day-to-day criminal activity near BART lines and stations. Direct observations by trained staff and secondary data collection (from BART as well as local jurisdictions) were also employed for a number of specific locations. The data collection process was complicated by unwieldy classifications of crime statistics and the inconsistency of the grouping of these statistics over time. Consequently, this information was synthesized from the various data sources as well as specific site studies to yield findings on the nature, extent and location of BART-related crime (TM, pp. 80-81).

Issues and Findings

BART Lines

Has crime or crime-related activity increased appreciably on or near BART lines in center city or suburban areas?

Typical BART line areas, such as those under the 24 miles of aerial structures and many line overpasses, do not appear to be used as hiding places for criminals, escape routes or focal points of increased criminal activity. An analysis of BART statistics on incidence of reported crime since the commencement of transbay service (September through December 1974) showed only a total of 14 trackway (not including station areas) crimes. Virtually all of the incidents were minor crimes such as vandalism; none were crimes against persons. In addition, local police reported no problems in these areas.

BART's linear parks constitute a special case. The El Cerrito and Albany linear parks include walkways with extensive landscaping on a 2.7-mile-long, narrow right-of-way beneath an aerial portion of the trackway. In Concord, a half-mile section of aerial line on a wider, but minimally improved, right-of-way can also be termed a linear park, although less formally. Crime in the linear parks and adjacent neighborhoods has not increased disproportionate to crime in other nearby locations (TM, pp. 84-86). The only exception to this has been infrequent vandalism of lights, trees and park furniture, all of which are typical of city parks in general.[1]

Despite this low incidence of crime, some elderly citizens in the El Cerrito area have complained to the police department about park security and view the linear parks as being unsafe. Direct observation, particularly in the Albany and El Cerrito linear parks, showed these concerns

[1] According to local police officials in the vicinities of the linear parks.

Plate 16
LINEAR PARKWAY BENEATH AND ALONGSIDE BART–EL CERRITO AREA

to be understandable. Randomly placed, low-to-moderate lighting, as well as landscaping and frequent aerial structure pillars, creates shadows which could provide hiding places for criminals. In the El Cerrito park, some parkway areas divide city blocks and are not visible or easily accessible from local streets.

Downtown Station Areas

Has crime increased appreciably in downtown BART station areas and been attributed to BART?

Stations designated "downtown" are those eight (plus Embarcadero Station not yet operating in 1975) in downtown San Francisco, Oakland and Berkeley as well as San Francisco's Mission district. All are subway stations in areas basically downtown and commercial in character, although in a few cases there are substantial residential populations nearby. No parking lots are provided here by BART, but street and pedestrian traffic is typically heavy. Most of the stations include small outdoor plazas, generally at street level.

According to police officials, local patrolmen, and analysis of BART crime reports, there have been few crime problems in these station plaza areas. The only criminal activities identified by BART police

officials[1] or station agents were infrequent purse snatchings and vandalism. BART data indicated 12 crimes in these areas during September through December 1974, only two of which were directed against persons.

To some extent, loitering occurs at all station plazas. Direct observation, as well as interviews with station agents, indicates that loitering neither deters patrons from using BART nor impedes pedestrian movement. However, police officials view the potential for crime as being higher when many idle persons congregate in an area than when there are fewer people and more constant movement.

All Other Station Areas

<u>What changes in crime or related activities have occurred in other station areas and been attributed to BART</u>?

Of the 25 BART stations in areas other than downtown, 23 have parking lots. Most are in residential or mixed residential/commercial areas. The incidence of crime in the neighborhoods near these stations has not been affected by BART. However, the reported incidence of parking lot crime is substantial. During September through December 1974, a total of over 600 crime reports were filed for such areas by BART police. Only 10 of these, however, were directed against persons; most were property crimes, while some involved narcotics or other miscellaneous offenses (Table 18). The three most frequent types of crime were found to be auto-related crimes (auto theft and burglary), petty theft and vandalism. These occurred in all the lots to some degree. It was found that these parking lots were generally unattended or patrolled, largely inactive at midday, and out of view of station agents due to station design. Auto-related crimes appear to be the most frequent types of crime in BART parking lots. These are also the only types of potentially BART-related crime found to be increasing appreciably in neighborhoods adjacent to stations. According to BART crime reports, 21 out of 23 stations with parking lots had auto thefts or auto burglaries during 1974 transbay service. One station, Coliseum, had approximately one-third more reported auto-related crimes during this period (21 reported incidents) than did any other station.

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[1] BART has an 80-person police force which patrols the system 24 hours a day. Although only a limited level of coverage is possible, all BART facilities including trains, stations, parking lots, lines and maintenance yards are patrolled.

Table 18
REPORTED PARKING LOT/PLAZA CRIME
(SEPTEMBER-DECEMBER 1974)

	PARKING LOTS				PLAZAS	
	Concord Line (6 Stations)	Richmond Line (6 Stations)	Fremont Line (9 Stations)	Daly City Line (2 Stations)	Daly City Line (2 Stations)	TOTAL
PERSON CRIMES						
Assault/battery	0	1	0	1	0	2
Strong-arm robbery	0	2	2	0	0	4
Purse snatching	0	0	4	0	0	4
PROPERTY CRIMES						
Auto theft, auto burglary	48	42	70	8	0	168
Petty theft	43	52	77	8	1	181
Vandalism	27	26	35	3	1	92
MISCELLANEOUS						
*Sex offenses**	1	0	5	0	0	6
Narcotics	1	1	9	0	0	11
Disorderly conduct	3	1	2	1	0	7
Suspicious persons	9	11	14	2	0	36
*Other***	20	15	40	21	1	97
TOTAL	152	151	258	44	3	

* No rapes were reported.
**Minor crimes and miscellaneous reports.

Auto theft and burglary increases in neighborhoods adjacent to stations are in the same locations that have the highest number of BART-patron autos parked on the streets (Fremont and Daly City). These stations have parking lot capacities of 700 and 820 respectively. In the Daly City area, more than twice the number of parked autos of BART patrons (over 1,000) were found on the streets than at any other station.[1] The approximately 500 autos of BART patrons parked on streets near the Fremont station are in an open space and commercial area with a low level of surveillance.

[1] A 1,500-car two-level parking garage (BART's first) is now under construction at this station.

Plate 17
BART STATION
AT DALY CITY

Plate 18
BART STATION
AT FREMONT

Interestingly, no appreciable increases in auto-related crimes have occurred on streets near the two non-downtown stations in San Francisco without parking lots (Glen Park and Balboa Park) even though both are sites of substantial BART on-street parking.

Petty theft (mainly theft of auto parts, bicycles and bicycle parts) and vandalism have increased appreciably in some areas but have tended to be confined to BART parking lots. There have been about the same number of petty theft incidents as auto-related crimes (168 versus 181). Where petty theft increased most (10 or more incidents), it occurred at stations located in low- or middle-to-low-income areas.[1] Although vandalism is the third most frequently reported crime, its incidence was considerably less; no station reported (for the period September through December 1974) more than 10 incidents, and all but four stations experienced some.

Generally, BART has had little or no effect on other property crimes or on person-to-person crimes in parking lots and neighborhoods adjacent to stations. There is one exception: several persons have been accosted in a pedestrian underpass at the Coliseum station. The underpass is a covered tunnel-like structure with hiding places, shadows, and little or no surveillance. In addition, it is located in a high-crime, low-income area.

Some suburban police officials also voiced expectations that urbanites would use BART as a vehicle for criminal activities in suburban station areas, but there has been no recorded evidence of this having occurred to date.

VISUAL EXPOSURE

The visual exposure study was undertaken to determine the extent of certain effects when BART trains began running near residences. It could be assumed that there would be some loss of privacy due to BART patrons being able to see into houses, apartments and rear yards. As shown in Figure 16, approximately 30 percent (or 21 miles) of the BART system is elevated and close enough to expose adjacent houses and yards to potential loss of privacy. It was also possible that commercial advertising would respond to the new "audience" with increased signage and new locations.

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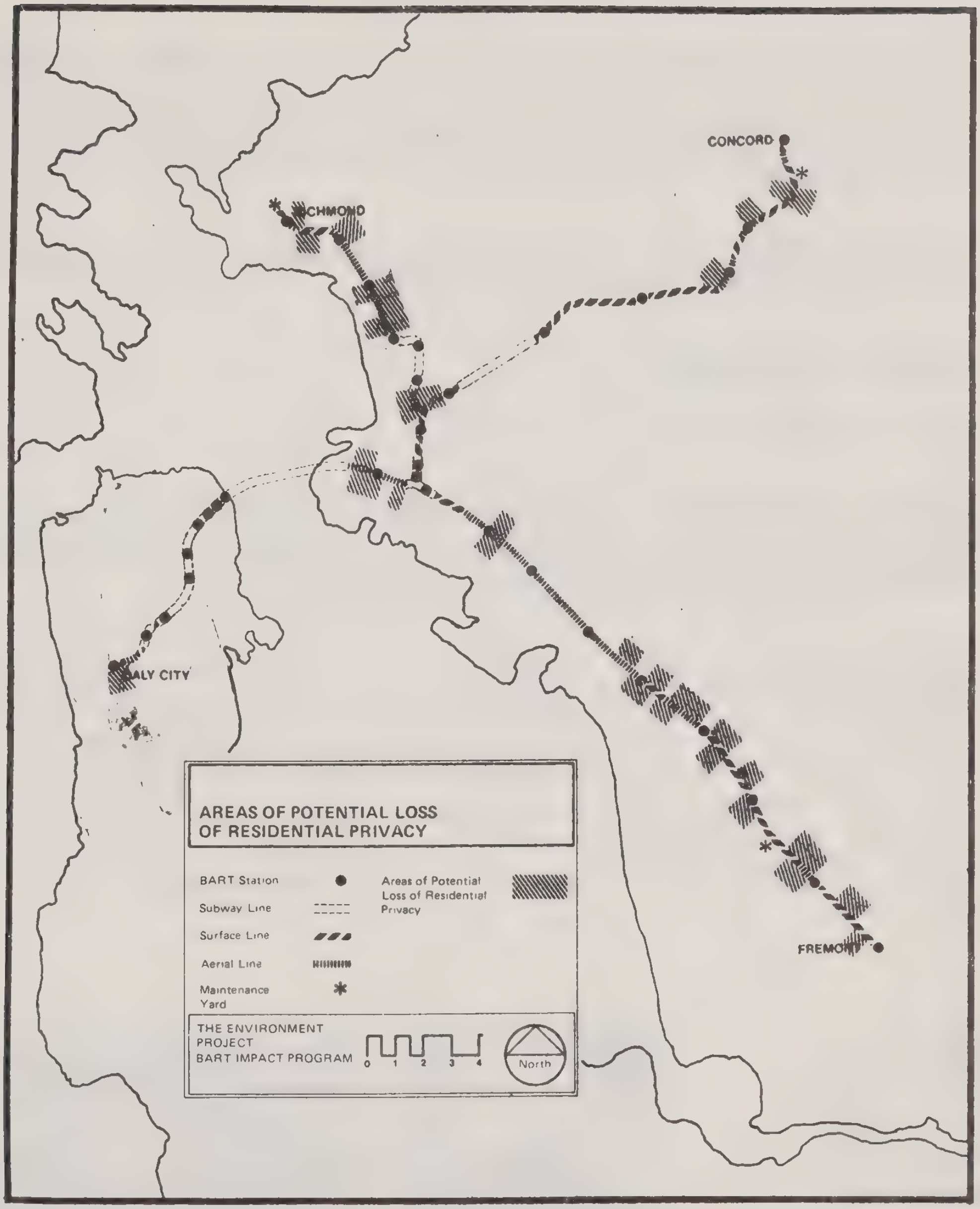
[1] South Hayward, Ashby, Coliseum, Rockridge, San Leandro, Fruitvale, and North Berkeley.

Figure 16
AREAS OF POTENTIAL LOSS OF RESIDENTIAL PRIVACY



Methodology

In the Phase I study, determination of the loss of privacy was limited to detecting any observable responses such as fences, window covering and more extensive landscaping. In order to accomplish this, photographs of selected residential areas were taken from the train and compared to a similar series taken in 1972.[1] In the Phase II study, detailed

[1] From the pre-BART REIS "View from BART" photo study (completed in 1972), which collected data on a wide range of environmental concerns and specifically included the privacy issue.

surveys of affected residents will be conducted to obtain actual "feelings" of loss of privacy and visual exposure.

To examine the possibility of increases in commercial and general advertising signage, a systemwide visual check from BART trains was made and a representative of Foster and Kleiser, a large outdoor advertising company, was consulted.

The two basic issues concerning visual exposure are presented along with their respective findings.

Issues and Findings

Loss of Privacy

In which of the areas that are potentially exposed to view from BART facilities have there been observable responses to potential exposure, and what types of response have occurred?

Approximately 21 miles of BART line have nearby residences that are exposed to potential loss of privacy. However, there are few observable responses to such loss. In one small area in Richmond, where apparent responses were observed, houses and yards are very close to the BART system. Passing trains run on a low embankment, placing train windows a few feet above rear fences and house windows. The observed responses at this site are extensive, including high fence extensions and total window coverings.

Plate 19
VIEW INTO RESIDENTIAL REAR YARD FROM BART TRAIN—EL CERRITO AREA

BART-Directed Advertising

In which of the areas where there is potential for BART-directed advertising have there been actual changes in advertising, and what types of changes have occurred?

Only two instances of signs clearly directed at BART were observed, neither being visible from nearby residences and streets. A number of communities along BART's right-of-way have enacted ordinances prohibiting advertising directed at BART riders in zones 330 feet to 1,000 feet on either side of the tracks. However, many billboards and commercial advertising signs on adjacent arterials are visible from BART as well as from the arterials.[1]

In discussions with a Foster and Kleiser representative, it was indicated that outdoor advertisers were not interested in directing billboards at transit riders. Difficulties created by high train speed, frequent preoccupation of riders with reading and face-to-face conversation, as well as the inability of many riders to see forward, were cited as incompatibilities between rapid transit and outdoor advertising.

[1] These signs predate BART in nearly every case, according to Foster and Kleiser.

VIII. BART IMPACTS ON THE VISUAL ENVIRONMENT[1]

INTRODUCTION

The purpose of the visual quality assessment of Phase I was to evaluate the effects of BART on the adjacent visual environment in terms of appearance, illumination and shadows. As with other studies within the Environment Project, the assessment focused on BART's impacts on its surroundings. This assessment deferred to Phase II of the Environment Project any evaluation of changes in visual quality as perceived by the rider in either train or station environments. During Phase II, effects of BART-related, induced development on the visual environment will also be evaluated.

The Phase I assessment examined both the regional and local visual impacts of BART on the Bay Area. The regional scale assessment identified and evaluated the repetitive visual elements of BART which could be perceived at the regional level and some of the urban form implications of the BART system on the Bay Area. The local scale assessment examined the impacts of transit facility improvements which have taken place in the visual environment immediately adjacent to the BART right-of-way. The purpose of the nighttime illumination study was to determine to what degree direct visible light sources, such as train lights, station lighting and parking lot illumination, are disruptive to nighttime visual environments. The shadow study evaluated the effects of shadowing on areas adjacent to elevated and at-grade guideways and stations.

REGIONAL VISUAL EFFECTS

The San Francisco Bay Area consists of a unique visual composition of urbanized areas shaped by the ocean, Bay and land forms. Urbanization has occurred within these physical parameters and has responded to them with bridges, distinctive downtown areas and activity centers, and relatively contained linear corridors of urban development.

While considerable low-density peripheral growth has occurred in recent years, this growth has been concentrated around satellite core areas and in established development corridors, leaving substantial areas of natural vegetation and open space, as well as the Bay, separating and

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[1] Gruen Associates (1976), Impacts of BART on Visual Quality - Interim Service Findings, Berkeley: Metropolitan Transportation Commission. References in this chapter to a Technical Memorandum (TM) refer to this document.

defining areas of development. In some areas, regional shopping centers have refocused commercial activity and added a new element to the regional urban form.

Methodology

The regional findings are primarily the result of extensive familiarity with the interaction between the BART system and major form-giving elements in the Bay Area. The findings, which are judgements made by a professional urban designer, are based on observations made from aerial reconnaissance and photography, ground reconnaissance from areas surrounding the system, and from reconnaissance aboard the trains and in the station areas. The impressions gained from these various perspectives merged into concepts or findings relative to visual relationships between BART and the region.

It should be noted that analysis of "urban form" can be very broad and elusive. For our purposes, the study concentrated on just two aspects: patterns of urbanization and visual image. The former is obviously more than just a visual phenomenon, as it encompasses physical, social, economic and political components. However, the visual aspects of urbanization patterns or urban form play an important role in its conceptualization and therefore should not be overlooked. BART's regional visual image is an effect of the system's repetitive and highly visible surface and aerial guideways, stations and informational and directional signs. Taken together they create a distinct new visual element and hence were included in the study.

Issues and Findings

What effects has BART had on the regional pattern of urbanization in the Bay Area?

BART has generally enhanced regional urbanization characteristics by following existing development patterns and major transportation corridors, and by not visually affecting major natural amenities. The location of primary BART destination stations in all eight of the major downtown areas in the three counties served by BART, combined with the development of plazas, pedestrian areas and refurbished urban streets, strengthened these areas. Transit service is also provided to 13 local activity centers and three regional commercial centers (Table 19). The physical and visual presence of BART in these areas contributes to a sense of regional cohesiveness resulting from the linking of centers by a common transportation system.

Table 19
URBANIZED AREAS SERVED BY BART

Central City Areas	Activity Centers	Regional Centers
San Francisco	San Francisco Civic Center	El Cerrito Plaza
Oakland	Orinda	Bayfair
Berkeley	Lafayette	Fremont Shopping Center
Concord	College Avenue	
Richmond	Glen Park	
Hayward	Mission Street	
San Leandro	Union City	
Walnut Creek	Daly City	
	Fruitvale	
	Alameda County Coliseum Complex	
	Ashby-Adeline	
	Pleasant Hill	
	Oakland Museum-Laney College	

Over 15 miles of freeways, the visually dominant existing regional transportation element, have been visually reinforced by locating stations and guideways in median and parallel alignments. An additional 20 miles of BART alignment are located alongside existing railroad tracks, and approximately 8 miles of the BART system utilize arterial rights-of-way.

The primary open space areas and San Francisco Bay have not been significantly visually changed by the BART system. The dominant visual urban form elements in the three counties in which BART is located and, to a large extent, in the entire Bay Area--the hills and the Bay--have been left visually unaffected by BART. BART crosses beneath the Bay in the Transbay Tube and in tunnel configuration through the Berkeley Hills, thus creating no visual impacts on the existing environment. All aerial and at-grade guideway segments (approximately 51 miles) are located in the flatlands below the hills in urban or semi-urbanized areas.

It was hypothesized that the general understanding and perception of the physical characteristics of the Bay Area have been improved for the users of BART. Because of the location of guideways along primary transportation rights-of-way and stations in or adjacent to activity centers, BART riders have been more exposed to the basic urban structure of the Bay Area than prior to the existence of BART. While this hypothesis has not been validated in Phase I, surveys scheduled for Phase II

will attempt to determine whether or not perception of the Bay Area has changed as a result of BART.

What elements of BART are present in the visual environment at a regional scale?

Elevated stations are the most numerous station type (20 of 34 stations) and are highly visible from adjacent developed areas. They are generally visually distinct from one another throughout the system, yet are easily recognizable as part of the total BART system. Underlying functional requirements, such as platform length, height, use of building materials and often the presence of parking facilities, create a repeated visual image. Aerial guideway structures, when located along arterial rights-of-way or in the median, constitute distinctive urban forms and are highly visible and uniformly recognizable elements of the BART system (TM, pp. 6-8).

Plate 20
BART TRAIN ON AERIAL GUIDEWAY–FRUITVALE AREA

The trains are highly visible and immediately identifiable as part of the BART system. They are visually unique as a transportation mode, uniform in appearance, and their motion catches the viewer's attention as they move through the above-ground areas of the system.

BART directional signs guiding motorists toward stations are distinctive and frequent and expand the visual image of BART beyond immediate station areas and visible system facilities.

LOCAL VISUAL EFFECTS

The assessment of localized visual effects of BART examined BART-related impacts which have taken place in the visual environment adjacent to guideways and stations. Changes in the local visual environment have been caused by the introduction of both static and dynamic BART elements. These include: guideways, trains, stations, parking facilities, landscaping, lighting, and pedestrian and vehicular areas.

Methodology

In contrast to the regional assessment, local visual effects were evaluated in a highly structured manner. First, based on observation of land use, degree of formality of buildings and open spaces, and density, size and scale of structures, all areas along BART's 71 miles were categorized into local visual settings. Six settings were identified (TM, pp. 39-40):

• Central downtown areas	3 miles
• Small downtown and commercial subcenter areas	5 miles
• Urban residential areas	18 miles
• Suburban residential areas	19 miles
• Industrial/commercial areas	11 miles
• Areas of open land and water	15 miles
	71 miles

Study sites (nearly 50) were selected based on their representing all of the identified local settings and various combinations of BART facilities (TM, p. 41). While the evaluation was site-specific, the representativeness of the settings permits systemwide assessment. Each study site was evaluated to determine the degree of BART's visual prominence and whether it reinforced or detracted from the local setting. The evaluation was made by comparing what the visual environment of the local setting would be without BART and what BART-related changes were introduced. Basic form elements, such as size, shape, mass, openness, linearity, height and movement, were compared for contrast and compatibility. The final step in the evaluation was to look at the appropriateness of the BART-related changes. Evaluation was based on urban design criteria, largely adapted from those used in the San Francisco Urban Design plan (TM, pp. 37-38).[1]

[1] San Francisco Department of City Planning (1971), The Comprehensive Plan: Urban Design, San Francisco: Department of City Planning.

The local visual evaluation and the subsequent findings tended to cluster around four central issues:

- Change in visual scale
- Change in architectural character
- Change in visual focus
- Change in street, pedestrian and open space areas

Issues and Findings

What visual scale changes have occurred as a result of the introduction of BART into existing urbanized areas?

The introduction of transit stations and guideways into existing urbanized areas results in changes in visual scale in some settings. BART structures and related open space areas that are significantly larger or smaller in scale, relative to the adjacent development, have resulted in changes in the visual environment.

The most prominent contrasts in the visual scale of the existing environment have occurred in areas where BART at-grade and aerial stations and guideways have been located immediately adjacent to urban and suburban residential areas. Approximately 32 miles of the system are in this pattern. However, much of that mileage is also alongside or within the median of other transportation facilities, a factor which tends to ameliorate the potential extent of impact. The large scale of the BART stations and guideways generally is not compatible with the typical smaller scale residential development. The introduction of large parking lots into residential areas created distinct contrasts in scale between the open parking facilities and the more closely spaced residential units.

BART aerial guideways in residential areas, when visually set off by adjacent open spaces of streets and railroad rights-of-way, make the difference between small-scale houses with BART's larger scale and form more evident. Aerial and surface portions of the system which run through residential areas but utilize freeway alignments or incorporate linear parks as part of the right-of-way tend to be more compatible with existing adjacent development. The scale, height and width of the freeway effectively screen the potential visual effects of BART. The linear parkways tend to soften the contrast between the massive BART structures and the smaller surrounding residential structures.

The scale of the structures found in three regional shopping centers (El Cerrito Plaza, Bayfair Center and Fremont) is similar to the scale of

the elevated BART station facilities adjacent to the three centers. The strong horizontal lines of the station and guideways are similar to the structural elements of the shopping center complex.

Plate 21
BART STATION ADJACENT TO REGIONAL SHOPPING CENTER— EL CERRITO PLAZA

BART aerial guideways, stations and parking lots are generally similar in scale to development in industrial/commercial areas. The large size and scale of industrial/commercial facilities and the pattern of land development in such areas are similar to or larger than the scale and character of BART facilities.

In two cases, the Union City and Coliseum stations provide a transition in scale from the massive forms of industrial and coliseum structures to smaller scale adjacent residential development.

In order to accommodate BART guideways and station facilities in the median of Highway 24, it was necessary to widen a portion of the freeway. After widening, the freeway became a dominant form element in contrast to the surrounding natural forms of hills and valleys. Cuts and retaining walls were increased in size due to the widening; however, the BART facilities within the freeway median have had little visual impact in this setting.

<u>How have BART stations and guideways attempted to reflect the architectural character of the adjacent development?</u>

The architectural character of the urbanized areas around much of the BART system was well established. The introduction of guideways,

stations and related facilities, which have unique architectural characteristics, reflect the architectural character of the surrounding structures mainly through structural design, the use of linear parks and landscaping.

The design of BART structures, particularly its aerial guideways, shows careful consideration to the problems of imposing a massive structure into residential areas. Attesting to the thoughtful design that went into the BART facilities are the numerous architectural awards the entire system, as well as individual components, has won (TM, pp. 31-32). However, it is one thing to have a well-designed facility, and quite another to be able to visually complement radically different adjacent development. About 60 percent of BART's aerial facilities are in residential areas, often in close juxtaposition with small-scale houses and local residential streets.

The designers responded to the challenge of visually integrating BART in three ways (TM, pp. 27-29):

- Support elements give horizontal scale to the structure. Their spacing and clear architectural expression, through decorative projections beyond the guideway, give the powerful horizontal form of the guideway a rhythm similar in feeling to that of nearby building facades, street trees and street lights.

- The massive appearance of the individual support elements or bents is reduced by careful articulation of their surfaces. Faceting of the columns and the gentle upward slope of the "T" arms permit the entry of light in such a way as to visually minimize massiveness.

- Visual overpowering of other smaller-scale form elements was reduced by separating the guideway structure into two parts, minimizing its cross-sectional bulk, and articulating it into several angled surfaces.

Landscaping stands out as perhaps the single most important design element in making BART's structure more compatible with small scale visual settings. Trees similar in height to the aerial structure help screen it from view or help break up its massiveness. The Pleasant Hill station has one of the largest surface parking lots in the BART system (1,400 spaces), yet, by retaining a stand of mature oak trees on the site and adding substantial new smaller trees, the parking lot was visually broken up into several small spaces, and the station and aerial structure are largely screened from view. The tall trees maintain a visual continuity with other existing trees in the area. In other instances,

landscaping was used to visually integrate stations and related parking facilities into a developed area by continuing existing neighborhood landscaping patterns onto the station site area.

<u>In what ways has BART influenced existing visual focus in areas surrounding BART, and in what ways has BART created its own visual focus?</u>

A BART station, because of the size of the structure and the movement of trains, persons, buses and vehicles around the station, creates a strong visual focus in most settings. This increased activity can reinforce an already-existing visual focus in the area or can create a new focus. This visual focus effect can significantly alter the visual character of an existing developed or open space area.

By locating some BART stations on the edges of established, small, downtown areas (Walnut Creek, Concord and Richmond), the visual focus of these areas has been shifted from the main downtown areas to the stations and the station-related parking and pedestrian areas. In Walnut Creek the BART station created a new area of visual focus four to five blocks north of the existing downtown, both through the station's size and its related auto and pedestrian movements. While BART's location in these areas is perhaps necessary for operational and traffic reasons, it has, at the same time, had the effect of diluting visual focus from one point to several.

At three regional shopping centers (El Cerrito Plaza, Bayfair and Fremont) the location of BART stations adjacent to these facilities reinforced the visual focus and visual activity of these centers. The increased activity related to the operation of the transit facilities complements the existing levels of activity in these areas.

Approximately 1.8 miles of the BART line on aerial guideway which is located in urban residential settings runs in the median of an arterial highway. This median location resulted in a shift of visual focus from the street and pedestrian areas to the guideway structure. This change in focus has tended to emphasize the guideways and trains in the residential settings and deemphasize the existing street and pedestrian areas as well as the smaller-scale residential structures.

A similar physical situation, but in a different setting, occurred with arterial streets in industrial/commercial areas. In these circumstances, strong and positive visual definition was achieved. In many cases, street facades were broken and visually discontinuous. The aerial guideway structures often effectively screened these broken facades from view and improved street definition. The BART aerial structure along San Leandro Avenue, south of the Coliseum station, is a good example of new, strong street definition BART provided in industrial/commercial areas while screening chaotic views from motorists.

BART guideways on embankments in parts of Concord, Hayward and Union City provided visual and physical separation of incompatible land uses by partially screening existing industrial areas from nearby residential areas.

Under what circumstances has BART affected the visual quality of surrounding areas by introducing changes to pedestrian, street or open space areas?

New pedestrian and open space areas in the form of plazas, sidewalks, linear parks and parking facilities were introduced into areas around BART. These new pedestrian elements, combined with increased BART-related pedestrian traffic, caused changes in the visual environment around the system. In addition to new areas, substantial portions of existing streets and pedestrian areas were refurbished. This, too, caused change to the existing visual environment.

In downtown locations in San Francisco, Oakland and Berkeley the existing urban streets and pedestrian areas were altered as a result of the construction of BART. Following the completion of construction, these areas were rebuilt, often far beyond the pre-BART condition. Changes in the quality of the visual environment resulting from the reconstruction of streets and pedestrian areas were most dramatic in downtown San Francisco, particularly along Market Street where extensive street and pedestrian area improvements dramatically add to the visual environment of the street. Market Street was graced with new street trees, widened sidewalks with new paving, reproductions of

Plate 22
DOWNTOWN STREET REFURBISHMENT—MARKET STREET, SAN FRANCISCO

historic street light fixtures and new street furniture, including benches and signs (TM, p. 11). The total cost of these improvements was approximately $34 million. This cost was shared by BART, the city and the local merchants. Similar, though less extensive, improvements were made to Broadway in Oakland and Shattuck Avenue in Berkeley.

In addition to street refurbishment in downtown locations, some urban residential areas where the BART line was constructed in a subway configuration had existing streets and pedestrian areas refurbished following completion of BART construction. For example, in Berkeley, Adeline Street and Shattuck Avenue were rebuilt utilizing extensive landscaping, street trees and street furniture. New parkway and vehicular traffic patterns were incorporated into the rebuilding program to improve traffic operations in Berkeley.

Linear parkways were developed in conjunction with BART aerial guideways along approximately 20 percent of the urban residential settings. In Albany and El Cerrito, a 2.7-mile parkway was built as an urban beautification demonstration project by the U.S. Department of Housing and Urban Development.[1] The prime objective of the project was to demonstrate how the rights-of-way under aerial structure could be treated so that the structure would be more aesthetically acceptable to the communities in which it is located and offer a more attractive view to the commuter.

The right-of-way on which the parkway is situated averages approximately 40 feet in width with some portions narrowing to 25 feet. Along

Plate 23
LINEAR PARKWAY—EL CERRITO AREA

[1] U.S. Department of Housing and Urban Development (1974), Linear Parkway, Washington, D.C., U.S. Department of Housing and Urban Development.

the other side of the entire BART right-of-way is the Santa Fe Railroad. The linear park consists of a continuous meandering walkway periodically developed for sitting areas, play lots and places of assembly.

The Albany portion of the linear park replaced a row of houses seven blocks long which were removed to accommodate the aerial guideway and widen the adjacent street. The linear form of the guideway can easily be seen because of the openness of the linear park next to the street. The scale and height of the aerial guideway, as well as its strong linear form, contrast with adjacent residential development. However, landscaping in the linear park reduces this visual contrast by partially breaking up the massiveness of the guideway.

No houses were removed to accommodate the development of the El Cerrito portion of the linear parkway. The aerial guideway and landscaping were placed in a channel between adjoining buildings previously created by the railroad right-of-way. The linear park forms a new landscaped pedestrian area within the existing urban residential neighborhood.

In Berkeley, along Hearst Street and in the vicinity of the North Berkeley BART station, a strip of vacant land was created by the cut-and-cover subway construction. Residential structures and landscaping were removed during construction. The City of Berkeley remains undecided about the ultimate use for this 1.3-mile corridor, and it is, many years after completion of BART construction activities, a visual detraction to the surrounding urban residential area.

<u>Where has BART been responsible for the most significant effect on the visual environment</u>?

Central downtown areas, regional shopping centers and industrial/commercial areas have generally been visually <u>enhanced</u> by BART. Major street improvements and plaza development have taken place in downtown San Francisco, Oakland and Berkeley. BART has been located adjacent to three regional shopping centers (El Cerrito, Bayfair and Fremont) and, consequently, brought additional attention or focus to these centers. In industrial/commercial areas, 11 miles of BART aerial structures and embanked guideway helped to visually clarify these areas and separate them from nearby residential land uses.

Alignment with freeways, the use of subway configuration and linear parks helped to make BART visually more compatible with adjacent development. Where parking lots have been concealed or not built, where BART is located near centers of activity or larger visual forms, and where landscaping has been generously used (especially mature trees), BART is visually more compatible with its surroundings.

Some smaller downtown areas were weakened by the peripheral location of visually prominent and active BART stations and parking lots. In residential areas, BART line and stations have had the most significant visual effect, primarily through introducing sharp contrast in scale and architectural character and by drawing attention to quiet and relatively inactive areas. These negative effects have been somewhat offset by linear parkways beneath a portion of BART's aerial structures.

In most instances, BART facilities have had little or no visual effect in areas of open land and water. Much of these areas are traversed by BART in either a tube beneath the Bay or in tunnel through the Berkeley Hills.

A summary indicating degree of visual effect by local setting is provided in Table 20. From the table it is apparent that the urban and suburban residential visual environments are the most affected settings.

Table 20
EVALUATION FACTORS AND EFFECTS ON VISUAL SETTINGS

Evaluation Factors	Central Downtown	Sub-Centers	Urban Residential	Suburban Residential	Industrial Commercial	Open Land and Bay
Visual scale	○	◓	●	●	○	○
Architectural character	◓	◓	●	●	○	○
Visual focus	○	●	●	●	◓	◓
New open space	◓	◓	●	●	○	○
Refurbishment of existing spaces	●	◓	◓	◓	◓	○

● Significant effect on visual environment.

◓ Some effect on visual environment.

○ No noticeable effect on visual environment.

ILLUMINATION

The operation of BART has resulted in increases in local levels of illumination which are primarily due to lighting installations around BART stations, parking facilities and maintenance yards. Increased nighttime operation of the BART system has also resulted in new light sources being introduced into the environment. As the operating schedules of BART are extended, the effects of nighttime illumination will increase. The assessment of the effects of BART-related illumination on the surrounding nighttime visual environment was conducted to determine the

degree to which these new light sources have affected the quality of the nighttime visual environment.

Methodology

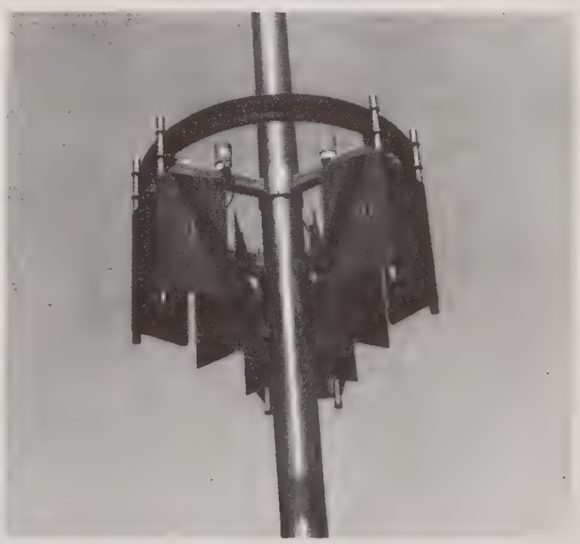
Field observations were conducted at selected sites to assess the effects of BART lighting on surrounding developed areas. The observations were made at six sites during nighttime operational periods. Photographs were taken to document the observed effects on the visual quality of the environment (TM, p. 40). It was assumed for the purposes of this study that urban and suburban residential areas were the most sensitive to changes in illumination levels. In addition, it was assumed that direct exposure to visible unshielded light sources was disruptive to the nighttime visual environment. These assumptions will be tested in Phase II as part of the response survey.

Issues and Findings

How does the design and placement of lighting systems affect the adjacent environment?

The impacts of BART illumination on residential areas were judged to be directly related to the design and location of lighting systems used to illuminate stations, parking facilities and maintenance yards. Special luminaire designs, such as were used in the Glen Park station plaza, minimize the horizontal spread of light while providing adequate lighting for the plaza area. This type of luminaire tends to minimize the effects of BART lighting on adjacent areas by reducing the amount of excess illumination outside the station area.

Plate 24
STATION ILLUMINATION—
GLEN PARK



In areas where efforts have been made to utilize luminaires which conceal light sources, the nighttime illumination of BART facilities has had less effect on adjacent residential areas than where no such effort was made. While shielding light sources may result in some slight reduction of effective light levels, adequate illumination levels can be maintained for safe and convenient operation of stations and parking facilities without excessive direct exposure of light sources to the surrounding community. In contrast, the high intensity luminaires mounted on tall poles used to provide general illumination of the BART maintenance yards resulted in maximum exposure of light sources to the adjacent developed areas. The overall illumination levels in the surrounding areas have thereby been increased significantly as a result of these installations.

What other factors determine the effects of BART lighting on the existing environment?

Adverse visual effects resulting from BART lighting were most apparent in residential areas adjacent to stations which have straight grid pattern streets and relatively flat topography. These conditions allowed for a maximum dispersion of light from BART facilities into surrounding developed residential areas. In locations where trees surround the parking facilities or where the topography is varied, the dispersion of light from stations and parking lots onto adjacent properties was reduced. Residential areas with relatively low levels of nighttime illumination and which were adjacent to BART stations experienced significant increases in the overall level of illumination from the exposed light sources on station structures and in parking facilities. This condition exists almost exclusively in residential areas.

SHADOWS

Shadows created by BART guideways and stations generally occur in those areas where the alignment is in an aerial configuration. These shadows provide either beneficial effects by creating shaded areas where there is no other shelter from the sun or can result in negative effects by preventing sunlight from reaching areas where it is desired.

Methodology

The assessment of daytime shadow impacts resulting from BART facilities utilized observations made at specific sites representing systemwide shadow conditions. Aerial guideways, which account for 23.6 miles of the 71-mile system, and elevated stations, the prime causes of shadows, were identified and categorized according to their orientation to the sun, height and surrounding land use. This information provided a preliminary indication of where the most significant impacts could be anticipated. Aerial photographs and BART track charts were used to

determine the location of potential shadow effects and adjacent residential development. These sites were observed at different times of day and year, and shadow lengths were projected using sun angle calculations. Photographs were taken at these sites, showing shadow effects of structures and moving trains.

Issues and Findings

What are the most significant determinants of BART shadow impacts?

During the course of the shadow assessment, four factors were found to be responsible for creating the majority of shadow impacts along approximately 7 percent (5 miles) of the 71-mile BART system.

- The height of guideways and stations relative to the adjacent land and structure
- The orientation of aerial guideways and stations relative to the position of the sun
- The proximity of structures and open space areas to aerial BART facilities
- The frequency of train operations

Plate 25
AERIAL
GUIDEWAY
CASTING
SHADOW—
EL CERRITO

Aerial guideways and stations are considered to be the primary source of shadow impacts on adjacent development. The alignment of aerial guideways in freeway and arterial medians, linear parks and in open areas generally resulted in shadows falling in these intervening open spaces rather than on nearby buildings. However, where shadow effects of BART do exist, they are considered to be similar to those created by trees, landscaping and other structures in that the shadow effect occurs for only a portion of the day and is dependent on the relative positions of the sun, transit structure and affected area.

IX. CONCLUSIONS AND IMPLICATIONS

INTRODUCTION

In the preceding five chapters, detailed Phase I findings were presented according to their general type of effect on the environment--acoustic, atmospheric, natural, social and visual. These findings are specific, numerous and diverse. The objective of this chapter is to sift and combine them to identify the key conclusions and lessons which can be drawn from this initial inventory of BART's environmental impacts.

Without doubt, the most far-reaching conclusion is this: BART has produced a generally low level of environmental impacts. This is particularly noteworthy when one takes into consideration that BART is 71 miles in length, has 34 stations, and traverses highly urbanized areas. However, this does not mean that all types of impact were insignificant, nor that all locations had minimal impacts. There were significant and potentially disruptive impacts in some places. These specific instances of impact had identifiable causes, as did the generally low level of impacts elsewhere.

These facts suggest the value of more specific conclusions and related implications. Several major topics can be identified as focal points for the organization of these conclusions:

- IMPACTS BY TYPE

  What is the overall effect of BART on each major component of the environment?
  What changes in these impacts are likely in the future?

- CAUSES

  What specific features of BART tend to cause its various environmental impacts?
  Do these causes tend to occur together (intensifying or offsetting impacts), or are they separate (trading off or substituting impacts)?

- LOCATIONS

  How are BART's impacts distributed throughout the system and region?
  Are any communities or population groups unduly affected?

- IMPLICATIONS

  What lessons can be drawn from these results for use in future urban transportation decision-making, both in the Bay Area and elsewhere?

The remainder of this chapter is devoted to presentation of the study's conclusions within each of these four topics. In order to avoid redundancy, most of the detailed findings supporting each conclusion are not displayed. The reader can refer to the preceding five chapters for such material; still further details of those findings are presented in the Technical Memoranda and Working Papers which correspond to each of the five chapters.

The Use of Normative Judgements in Impact Interpretation

To present conclusions on environmental impact concisely but with a minimum of distortion, it is necessary to consider both the normative nature (positive/negative) and intensity (major/minor) of impacts, both singly and in the combinations which occur at different locations. It is natural to ask "Were BART's environmental impacts mainly positive or negative?" In the use of such terms, it is implied that everyone agrees on what is positive and what is negative. For most specific environmental impacts, such as sound and safety, this appears to be reasonably true.

More open to contention are judgements concerning the intensity of "goodness" or "badness" of an impact. Even more contentious is any attempt to compare quite different impacts--such as the sound of BART trains on an aerial track and the visual impact of that aerial track in a new landscaped linear park -- and conclude that one impact offsets (or adds to) the other so that the net result is either "good" or "bad." There is almost certain to be disagreement on such conclusions, despite the tendency to attempt them.

In this Project, normative judgements are limited to individual impact categories. Further conclusions regarding the net result of simultaneous positive and negative impacts are avoided. Such conclusions are left to each user of these findings, in order to allow the application of rules of judgement appropriate to that user's needs.

Here, the following assumptions are made:

- Any increase in sound, vibration, barriers or visual exposure is a negative impact.

- Any decrease in air quality, safety, or security is negative.

- Any change in microclimate, natural environment, or visual character is negative.[1]

- A major impact is defined as any which--in the consensus judgement of the study staff--would probably be objected to (or if positive, approved) by most reasonable and informed persons residing near it.

- A minor impact was defined similarly, as any which was found with reasonable certainty to exist even though many reasonable and informed persons might not notice or respond to it.

- A positive impact of one type, whether major or minor, does not cancel out a negative impact occurring in the same place; each should be reported individually.

IMPACTS BY TYPE

The central issue here deals with the five key environmental components. What is BART's overall effect on each? In addition, some of BART's operational characteristics, most notably its hours of service, train frequency, and patronage, are to change as the system matures. Thus, on which components of the environment can impacts be expected to change?

Acoustic Environment

BART trains were found to cause a measurable increase in community sound levels. This impact occurred along approximately nine miles of the system, which were predominantly residential areas. In those locations, this was potentially disturbing only to those within about a block of the tracks.

More significant, however, is the conclusion that planned increases in BART's operating hours (at the time of this study yet to include evenings and weekends) and level of service (more frequent trains) will expand this impact to include virtually the entire mileage of residential neighborhoods abutting BART's above-ground tracks (approximately 44 miles).

[1] See Visual Environment Technical Memorandum Report (op. cit.), pp. 37-38, for exceptions and explanation of this general assumption.

Intensity of the aggregate sound level impact will also increase in locations already impacted, which will in turn increase the probability of disturbance to residents and others.

BART train-induced vibration levels adjacent to both aerial and subway lines were found to be similar to those of a passing truck. Although measurements were taken at only two sites, these tentative results indicate potential disturbance to nearby residents. Further measurements are required in Phase II to verify these initial conclusions and to examine the hypothesis that such effects may increase as the BART trains and tracks age.

These impacts deserve careful study in the Phase II interviews with nearby residents in order to ascertain the relationship of these instrument measures to actual perceptions of BART noise and vibration.

Atmospheric Environment

BART's small diversion of auto users to transit has resulted in a minimal decrease in the region's level of automobile-generated air pollutants. Anticipated increases in BART's patronage will not materially change this. It is therefore concluded that BART is not now a major factor in air quality improvement in the Bay Area, nor will it be in the future unless unanticipated conditions produce a very much larger patronage increase than now foreseen.

Air pollution in the vicinity of suburban BART stations has been increased in some instances due to traffic within and en route to the BART parking lots. However, even at a large and heavily used lot, this impact has been very small, both in intensity and area of coverage. Pollution levels potentially harmful to health are not approached, even under atmospheric conditions most conducive to such impact (i.e., little or no wind). The low and sometimes nonexistent impacts recorded indicate that conditions of air stagnation and BART-bound auto traffic would have to be much more extreme than expected in the Bay Area for such local air pollution effects of BART to become serious.

BART's effects on microclimate--wind and temperature--appear to have been minimal or nonexistent. Conditions were found with a potential for increasing wind velocity when forced under elevated station or track sections or across large open surfaces such as BART parking lots, but few such effects were actually identified. Although it was originally suggested that the subway and Transbay Tube ventilator shafts might produce annoying heat or wind effects when their outlets were at street level, no such effects were found. No future changes are to be expected.

Natural Environment

BART has had virtually no impact on the biota, soils and geology, and water systems of the region. However, application of this conclusion elsewhere must be tempered by the fact that the specific areas traversed by BART were predominantly urban; even where less intensively developed land was crossed, it was found to be largely insensitive to such impacts. No changes in such impacts are to be expected in the future as BART's service and patronage expand.

Social Environment

BART's overall impact on the social environment, defined in this study to include safety, security, physical barriers, and privacy (visual exposure), was generally small. Safety problems were found as a result of increased parking and traffic only near a few of the suburban BART stations. Even in most of these areas, safety problems were not serious, and can be remedied. However, without such remedies, these impacts may increase with forecast increases in BART patronage and parking lot use. Personal security appears to be unaffected except for some incidence of auto-related crime in and near BART parking lots. Although more security problems may emerge with increased patronage and evening service, this is as yet only an hypothesis for Phase II study. Virtually no new barriers to local movement have been created by BART, despite its crossing of several hundred streets and pedestrian paths. In a few locations, BART's addition or improvement of pedestrian/auto crossings of railroads and arterial streets has increased safety, though often at the same time decreased convenience. A beneficial barrier impact occurred in several suburban locations where BART's trackway embankments effectively separated areas of industrial and residential use. Finally, although many previously private areas such as backyards are now exposed to the view of BART passengers, there have been only minimal attempts either to block this view or to capitalize on its advertising potential. It is therefore concluded that this has not been a significant impact.

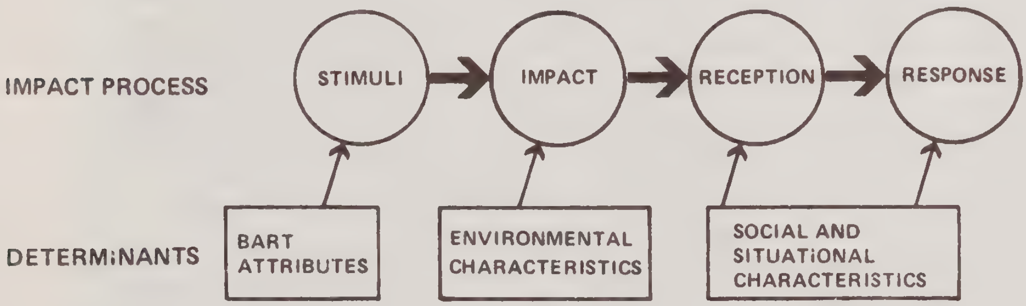
Visual Environment

BART's impact on neighborhood visual quality has been varied. In some locations it has significantly altered the existing image. This has been generally adverse in suburban residential and open areas where BART's large structures tend to dominate the visual scene. Conversely, in downtown areas, shopping centers, and industrial sections, BART's visual effect has been generally supportive and enhancing of the existing image. Downtown street refurbishing and the linear parks are particularly positive impacts displayed by the system. These impacts are expected to continue without change.

Visual impact at a regional scale is essentially conceptual, but it may be concluded tentatively that BART's easily identifiable stations, aerial lines, and display graphics have contributed to strengthening the public perception of the region as a cohesive unit. This will be tested further as a Phase II interview survey hypothesis. Finally, both nighttime lighting at BART parking lots and daytime shadowing by its aerial lines are noticeable throughout the system. However, these impacts do not appear to have significant consequences on the visual environment, nor are they expected to change substantially in the future.

IMPACT CAUSES

As presented in Chapter II, this study's organization is based on a simple model of the relationship of impacts and their causes:



In this model, a BART environmental impact is created by the effect of a given BART attribute on a specific environment; both are determinants (contributing causes) of the impact.[1]

For each of the potential determinants of BART's environmental impacts, there are generally several options. For example, line configuration (a BART attribute) may be either subway, at-grade or aerial; similarly, adjacent land use (an environmental charactersitic) may be residential, commercial, or some other category. For some determinants, each option tends to lead to distinctly different environmental impacts. It is therefore useful to look at causes in terms of some of the major tradeoffs of impact which occur among such options. These same conclusions can also illuminate some of the tradeoffs between this study's environmental impacts and other kinds of impact, such as cost and user convenience (which are topics of other BIP studies).

Table 21 shows that substantial impact tradeoffs do occur between options for a given impact determinant. Details on each of the impacts

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[1] The remainder of the process, including the individuals' reception, perception and reaction to impact, and the effects of specific social/situational determinants, will be a major topic of Phase II.

Table 21
BART ENVIRONMENTAL IMPACT CAUSES AND EFFECTS

Impact Determinants	TYPES AND MAGNITUDES OF IMPACT				
	Acoustic	Atmospheric	Natural	Social	Visual
I. BART ATTRIBUTES: FACILITIES					
Line Configuration					
Aerial	●			○	●
At-grade (embanked)	○		○	○	○
Subway					
Track Engineering					
Many switches and curves	●				
Few switches and curves	○				
Station Access					
Primarily auto		○	○	●	●
Primarily bus				○	
Station Design					
High contrast to environment					●
Similar to environment					○
II. BART ATTRIBUTES: OPERATIONS					
Hours of Operation					
Daytime only	○			○	
Day and night	●			*	○
Train Frequency					
Frequent (2 to 6 minutes)	●				○
Less frequent	○				
Train Speed					
80 mph	●				
40 mph	○				
Patronage [1]					
High patronage				●	○
Low patronage				○	
III. CHARACTERISTICS OF BART'S ENVIRONMENT					
Adjacent Land Use					
Residential	●			○	●
Commercial/industrial					○
Undeveloped/open/recreational			○		○
Adjacent Transportation					
None	●		○	○	●
Low-use railroad or arterial	●			○	○
Heavy-use railroad, arterial or freeway	○				
IV. SOCIAL AND SITUATIONAL CHARACTERISTICS (Age, income, ethnicity, activities involved, personal sensitivities)	(to be studied in Phase II)				

● Major impact
○ Minor impact
* Not possible to assess in Phase I

1 Although patronage is technically a BART travel impact rather than an attribute of the system's operations, it is included here in recognition of its present and potential environmental effects.

summarized in this table were presented in the preceding five chapters. In particular, the table highlights the complex effects of choices between aerial and at-grade line configurations, residential and nonresidential station and line locations, and the emphasis or deemphasis of station access by automobile. It is evident that, of the main BART attributes, aerial trackway configuration and large parking lots are major causes of environmental impact in contrast with other options. Among the environmental characteristics, residential location and the absence of other busy transportation activity are both important impact determinants.

Typically, BART's attributes and environmental characteristics were found to occur in combinations which had significant effects on the occurrence and intensity of impact. Some of these are evident in Table 21. Others involve steps which were taken specifically to offset some of BART's negative impacts. These combinations of impact causes may be summarized separately for stations and lines, as shown in Table 22

Table 22
ADVERSE IMPACT DETERMINANTS COMMONLY OCCURRING IN COMBINATION ON BART

	DETERMINANTS BY TYPICAL LOCATIONS		
Impact Determinant Types	**Downtown Stations***	**Outlying Stations**	**Surface Lines***
I. BART Attributes			
- Facilities		- Large parking lot - Lot layout with auto-pedestrian conflict - Visually massive station structure - Aerial trackway - Minimal landscaping - Trackway switches	- Aerial configuration - Curve, switch, or tunnel portal - Narrow right-of-way - No landscaping
- Operations		- High patronage, most arriving by car - Night service - Bright parking lot lights	- High train speed - Frequent trains - Long trains - Night service
II. Environmental Characteristics		- Residential area	- Residential area - Lightly used adjacent railroad or arterial
III. Social and Situational Characteristics		(To be studied in Phase II)	

* Subway lines and stations (downtown) were found to have no apparent environmental impacts beyond construction, which was outside this study's scope. Possible security impacts arising from night service will be studied in Phase II.

for adverse impact causes, and Table 23 for causes of reduced adverse impacts.

Table 22 illustrates the conclusion that BART's suburban stations and above-ground lines are often subject to a wide variety of adverse impact causes acting simultaneously. Table 23 summarizes the actions actually taken in some locations by BART which in this study were found to be effective in reducing or offsetting some of the typical adverse impacts. From these tables may be drawn the conclusion that, despite the many kinds of adverse impacts occurring at some stations and lines, BART did demonstrate a number of effective countermeasures which helped to hold its overall impacts to a generally low level.

Table 23
IMPACT DETERMINANTS FOUND EFFECTIVE IN REDUCING BART'S ADVERSE IMPACTS

Impact Determinant Types	DETERMINANTS BY TYPICAL LOCATIONS		
	Downtown Stations	Outlying Stations	Surface Lines
I. BART Attributes			
- Facilities	- Subway configuration - Street beautification program - No parking facilities - Station plazas	- No parking facilities - Siting near other nearby large structures - Minimum use of street frontage (low visibility) - Parking lot layout to minimize mode mixing - Landscaping to match neighborhood (especially preservation of large trees) - Division of parking lot into smaller visual units - Glare-free lighting	- Well-designed structure, visually simple - Frequent crossings - Linear parks - Other landscaping
- Operations		- Bus feeder service emphasis	- Lower speed - Less frequent trains - Daytime operation
II. Environmental Characteristics		- Shopping center or commercial area - On edge of residential area rather than within	- Non-residential area - Beside or within heavily used railroad, arterial or freeway right-of-way
III. Social and Situational Characteristics		(To be studied in Phase II)	

LOCATIONS OF IMPACT

The Environment Project's approach was first to assess impacts and identify their causes at a number of locations. The broader incidence of impact throughout the BART system was then estimated by inventory of these causal conditions throughout the system, followed by selective on-site checks.

Figure 17 is a simplified presentation of the overall impacts by location. Some readers will be particularly interested in the locations themselves, but many others will find this presentation useful for another reason: it shows the degree of dispersal versus concentration of impact throughout the BART system. Analysis of the material in Figure 17 leads to the conclusion that impacts are widely scattered throughout the BART system, with the greatest concentrations at East Bay suburban stations and along some of the aerial trackway.

Population Groups Affected

Given these impact locations, have any population groups been especially affected? Table 24 shows that proportions of low-income families, blacks, persons of Spanish heritage, and elderly are all higher in the census tracts nearest BART than in the Bay Area as a whole.

Table 24
SPECIAL POPULATION GROUPS AS PROPORTIONS OF TOTAL POPULATION IN BAY AREA AND NEARER TO BART

	Bay Area SMSA	Three-County BART Area	Census Tracts Nearest BART
Low income (under $7,000)	22%	24%	31%
Black	11%	13%	20%
Spanish heritage	12%	13%	16%
Elderly (65 and older)	10%	8%	11%

Source: 1970 U. S. Census of Population.

Analysis of the affected population may be made more specific by identifying census tracts (and smaller areas where data allow) in which these same population groups are most concentrated.[1] Figure 18 displays the locations of such concentrations and shows that they occur

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[1] For most of these variables, census block data are not available. To estimate locations of such population group concentrations below the level of census tracts, hypothetical contours of equal concentration were mapped based on tract population centroids and the tract level data.

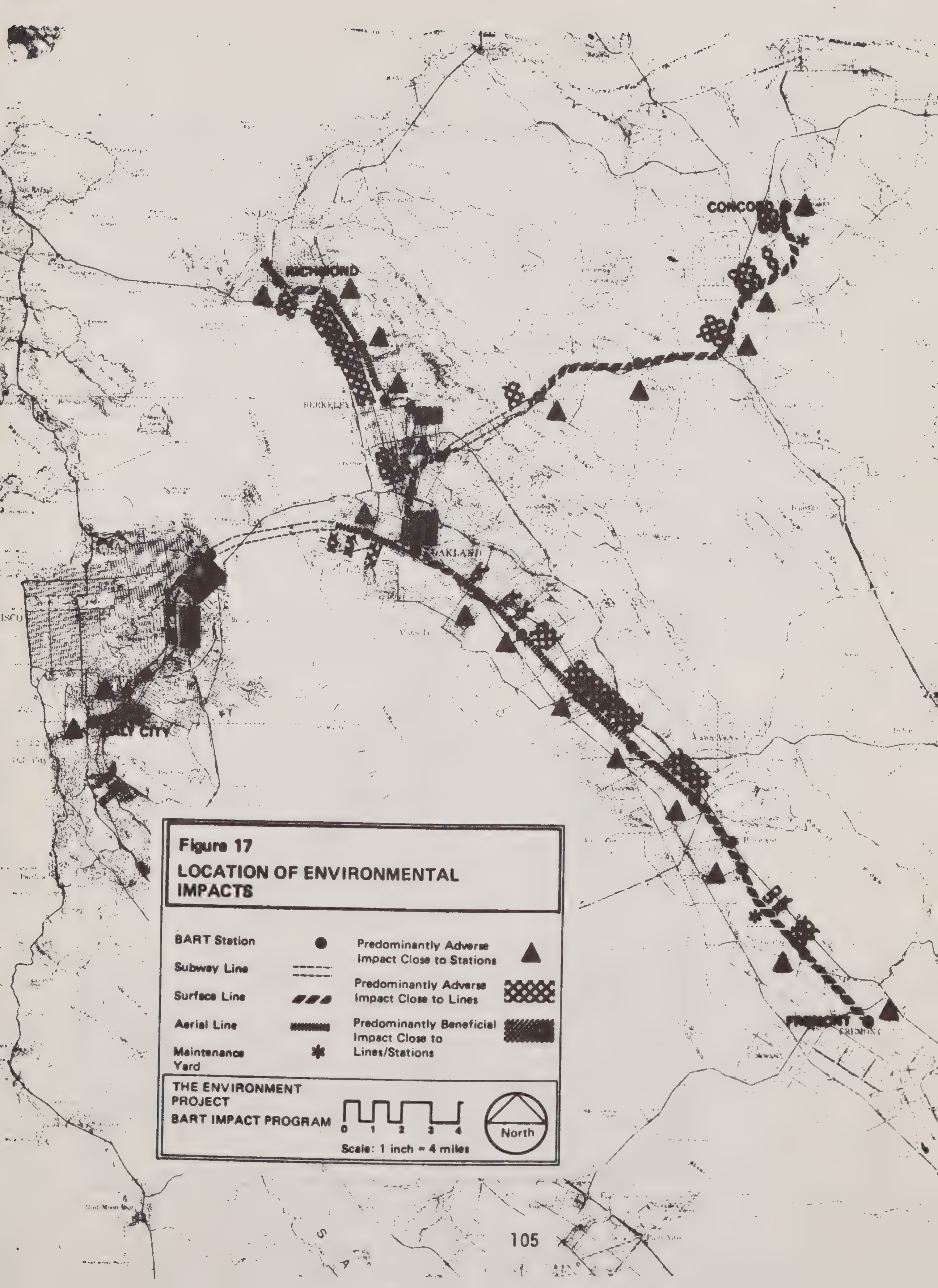


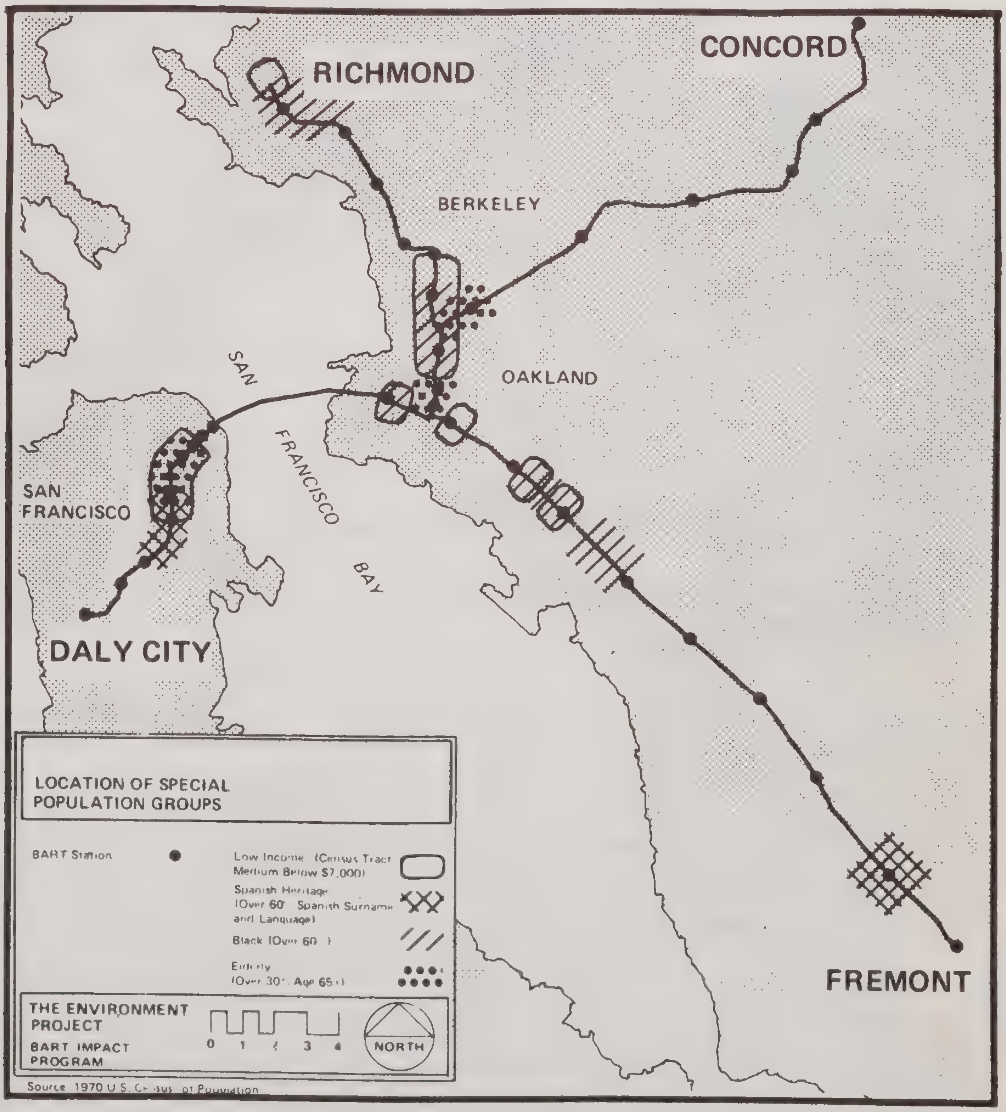
Figure 17

LOCATION OF ENVIRONMENTAL IMPACTS

near only a small part of BART's total length. The figure also indicates the locations of BART's aerial lines and stations with parking, which were found to be the system's major points of environmental impact. Inspection of this figure shows that concentrations of the population groups of interest here occupy only a small proportion of the areas most heavily affected by BART's adverse environmental impacts. Numerically, these population group concentrations occur adjacent to approximately 4 of the 17 miles of BART lines found to have adverse impacts, and 5 of the 21 stations with adverse impacts. Thus, it is concluded that most of these impacts are focused on other groups, predominantly middle- and upper-middle-income persons.

For more details on specific impact locations, the reader may refer back to Chapters IV through VIII, comparing the impact locations reported for each impact category with the population group concentrations of Figure 18. However, none of these distributions indicate more pronounced effects on these low-income and minority population groups.

Figure 18
LOCATION OF SPECIAL POPULATION GROUPS



IMPLICATIONS: LESSONS FOR THE FUTURE

To this point, the BART Environment Project's Phase I findings and conclusions have been presented without comment as to their potential application. However, a number of lessons may be drawn from the study of BART to the benefit of urban transportation decisions yet to be made both in the Bay Area and elsewhere. This section suggests a number of such lessons.

The decisions <u>to</u> build a rapid transit system and <u>how</u> to build it are not simultaneous but iterative. At each stage of commitment, new and increasingly more detailed issues arise and must be resolved in order to proceed with the system's planning and design. Many of these issues are environmental concerns.

At the earliest stages there is only one environmental issue: <u>Is environmental impact likely to be a major problem</u>? Only a general answer is required. As debate and study continue and decision options become more detailed, ever more specific issues of environmental <u>sensitivity</u> to each new option begin to emerge:

<u>What happens to the environment if we put it here instead of there (environmental characteristics)? Or build it like this instead of that (BART attributes)?</u>

This suggests a corresponding presentation of this study's implications. First, general implications for environmental impact are suggested. The remainder of this section is devoted to implications for the <u>sensitivity</u> of environmental impacts to the alternatives available for each of the major transit system planning and design decisions:

- Line location and configuration
- Station type and location
- Intensity of operations
- Facility design details

These decision alternatives tend to combine options for specific BART facility/operations attributes and adjacent environmental characteristics. That is, the issues for decision tend to be of the form "<u>How</u> should it be built if placed <u>there</u>?" or "<u>Where</u> should it be if built <u>this way</u>?" Therefore, some of the implications drawn in the following paragraphs merge BART attribute and adjacent environment options into a single statement, indicating their close relationship.

General Implications: Environmental Impacts of Rail Transit

- It is apparently possible to build a large rail rapid transit system with a generally low degree of adverse environmental impact if busy transportation rights-of-way and non-residential areas are available for much of its route.

- The improvement of regional air quality attributable to even a major rapid transit system is likely to be minimal unless it succeeds in diverting a much larger proportion of a region's auto trips than did BART.

- In urban areas, a transit system's impacts are at least as likely to fall on the human environment (social, acoustic, visual), particularly its acoustic component, as on the natural or atmospheric environment, so careful attention should be given to both.

Sensitivity of Impact: Line Location and Configuration

- Although use is limited due to cost, there appear to be no significant environmental impacts of subway transit lines, apart from initial construction disruptions and possibly perceptible vibration.

- Most environmental impacts along an above-ground transit line do not extend beyond the immediate blocks abutting the line.

- Impacts are likely to be substantial when at-grade or aerial transit lines are placed in residential areas. Aerial trackways minimize barrier effects but expose their surroundings to substantially greater acoustic and visual impacts than do at-grade configurations.

- Use of active prior transportation rights-of-way, particularly those of freeway medians, can result in substantial mitigation of impact. Conversely, environmental impacts of transit lines, particularly if elevated, built on transportation rights-of-way, can be severe if prior intensity of use was low or if the rights-of-way are narrow. The resulting impacts may offset initial cost savings and displacement problems.

Sensitivity of Impact:
Station Location and Type

- Impacts are likely to be substantial when stations are located within established residential neighborhoods.

- Most environmental impacts at stations do not extend beyond the nearest few blocks surrounding the station.

- The most significant station impacts are likely to be in the areas of visual quality and traffic safety.

- Particularly large and diverse negative impacts are likely to occur at large collector stations with heavy use of autos for access (especially with parking lots), in contrast to stations with less parking and more bus access service.

- All else equal, line terminal stations are probable sites of the most severe station-area impacts, due to their high patronage and automobile access.

Sensitivity of Impact:
Intensity of Operations

- High train speed and frequency are major operational causes of acoustic impact.

- Nighttime service may be the source of a transit system's most severe acoustic impacts on adjacent residential neighborhoods.

Sensitivity of Impact:
Design Details

- Abrupt track changes such as switches, bridges and subway portals are likely points of significantly increased acoustic impact.

- Traffic controls in and around parking lots must be carefully designed to avoid creation of unnecessary hazards. Layout of station parking lots should avoid mixing of pedestrian patrons and various types of vehicles by use of separate routes and station entrances.

- <u>Landscaping</u> can be very effective in reducing adverse impacts of stations, their parking lots and aerial lines and earth embankments. The use of <u>linear parks</u> is a particularly effective means of counterbalancing the adverse impacts of aerial trackways in residential areas.

- The <u>architectural design and siting</u> of transit stations and lines need the utmost care if they are to be made compatible with their surroundings. This is especially true in residential settings where the transit facilities are inherently out of character.

EPILOGUE: PHASE I IN PERSPECTIVE

Several months have passed between the completion of the Phase I research and the final drafting and editing of this report for publication. Meanwhile, BART service has continued to change and mature, and the Phase II study has begun. It is therefore appropriate to conclude this Phase I Final Report with a brief reminder of its interim nature and a look ahead at Phase II.

The scope of Phase I has been limited, as described in this report's first chapter. Not all environmental impacts were assessed, especially those arising out of land development changes which may have been (or will be) caused by BART. The BART impacts studied were not contrasted to those which would be expected under alternative means of urban transportation. And the opinions and actions of the people who have borne these impacts were not investigated. All of these things are to be included in the Phase II study.

Finally, BART itself was in an interim stage of operation. Since then, limited weekday evening service has begun, although the planned ultimate level of service will not be reached until 1977 or later. This will allow study of nighttime sound impacts and possible security problems during the dark hours. Also, the final station (Embarcadero, at the foot of Market Street in downtown San Francisco) is scheduled to open during the Phase II study, as is a parking structure intended to relieve the parking and traffic problems at the Daly City station. Both of these new facilities should produce changes in the system's environmental impact. BART is also continually making improvements in its existing facilities and operations, such as standardization of traffic control signs and markings in its parking lots. All of these will be closely monitored and reviewed in Phase II.

With the addition of the Phase II component, the Environment Project's findings will provide a comprehensive picture of the environmental effects of a modern heavy-rail transit system. But this Phase I Final Report alone has presented many detailed findings of immediate value in the planning and design of the upcoming generation of urban transit systems. It is also a potentially valuable tool in the evolution of Federal policy concerning the encouragement in the future of rail systems such as BART as well as other forms of urban mass transit.

ENVIRONMENT PROJECT PHASE I DOCUMENTATION

- Interpretive Summary*
- Environmental Impacts of BART* Interim Service Findings (1976)
- Acoustic Impacts of BART* Interim Service Findings (1976)
- Impacts of BART on Air Quality* Interim Service Findings (1976)
- Impacts of BART on the Natural Environment* Interim Service Findings (1976)
- Impacts of BART on the Social Environment* Interim Service Findings (1976)
- Impacts of BART on Visual Quality* Interim Service Findings (1976)
- Theory Background for Study of BART's Impacts* (1976)
- Pre-BART Data Analysis * (1975)
- Community Monitoring* (1976)
- BART and Its Environment: Descriptive Data (1976)
- Research Plan* (1975)

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*** Document is available to the public through the National Technical Information Service (NTIS), Springfield, Virginia 22151. Other documents are MTC internal working papers.**